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Ship Navigation Simulation Study, Port Jersey Channel, Bayonne, New Jersey

Volume I: Main Text

by Michelle M. Thevenot, Carl J. Huval, Larry L. Daggett

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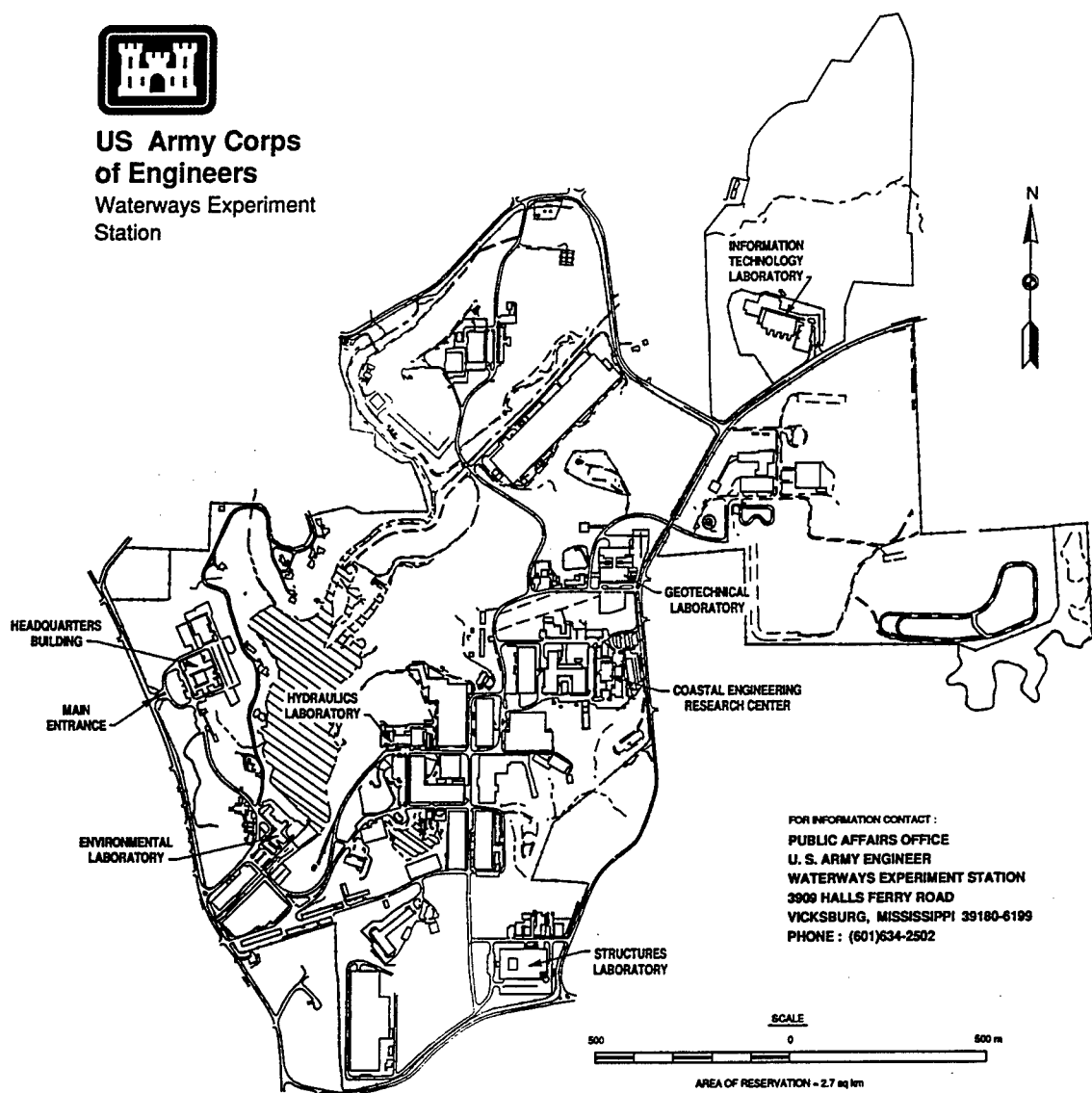
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Preface

This investigation was performed by the Hydraulics Laboratory of the U. S. Army Engineer Waterways Experiment Station (WES) for the U. S. Army Engineer District, New York (NAN), during the period August 1988-February 1990. The study was conducted with the WES research ship simulator. Authority was given by New York District. New York District provided the essential field and model data required.

The investigation was conducted by Ms. Michelle M. Thevenot, Mr. Carl J. Huval, and Dr. Larry L. Daggett of the Ship Simulation Group, Waterways Division, Hydraulics Laboratory, under the general supervision of Mr. Frank Herrmann, Jr., Director of the Hydraulics Laboratory, and Mr. M. B. Boyd, Chief of the Waterways Division.

Acknowledgement is made to Ms. Diane Rahoy, Engineering Division, NAN, for cooperation and assistance at various times throughout the investigation. Special thanks should go to Moran Towing, Turecamo Towing, and Sandy Hook Pilot Association for furnishing professional pilots to con the ship during the simulator tests on the WES ship simulator.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

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Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

| Multiply | By | To Obtain |
|-----------------------|------------|-------------------|
| cubic feet | 0.02831685 | cubic meters |
| degrees (angle) | 0.01745329 | radians |
| feet | 0.3048 | meters |
| knots (international) | 0.514444 | meters per second |
| miles (U.S. statute) | 1.609347 | kilometers |

1 Introduction

Physical Description

The study area is adjacent to the Federal navigation project known as New York Harbor and is located within the Port of New York and New Jersey, the leading port on the Atlantic Coast of the United States (see Figure 1). This channel is at a right angle to the main Anchorage Channel just north of the Kill Van Kull Channel. The Port Jersey Channel provides primary access to the peninsula of vacant land owned by the Port Authority of New York and New Jersey on the northeast end of the channel, Global Marine Terminal (GMT) located at the northwest end of the channel and the U. S. Army Military Ocean Terminal (MOT) on the south side of the channel. It is not currently a Corps of Engineers project. The existing Port Jersey Channel is 35-ft deep below mean low water (MLW) and 750-ft wide with a 1,200-ft turning basin at the end of the channel. A more detailed view of the study area is shown in Figure 2.

The New York Harbor and Adjacent Channels study was the result of the New York Harbor and Anchorage Channels study adopted 5 December 1980. Local interests, namely the Port Authority of New York and New Jersey, were studying the feasibility of developing a major coal handling facility for the export market at Port Jersey, Bayonne, New Jersey. In October 1984, the Port Authority of New York and New Jersey announced its decision to postpone the development of a coal export facility. At this time a car carrier facility is under consideration. Studies to date show that the Port Jersey Channel improvements appear to be justified. The Water Resources Development Act of 1986, Section 202 authorizes construction of a 45 foot channel at Port Jersey as part of the New York Harbor and Adjacent Channels authorization.

Seasonal salinity variations within the upper bay are primarily a function of the variation in the freshwater flows of the Hudson River, with lower salinity levels in the spring and summer correlating directly with the high spring runoff. The harbor can be considered well mixed with bottom levels slightly higher than surface concentrations.

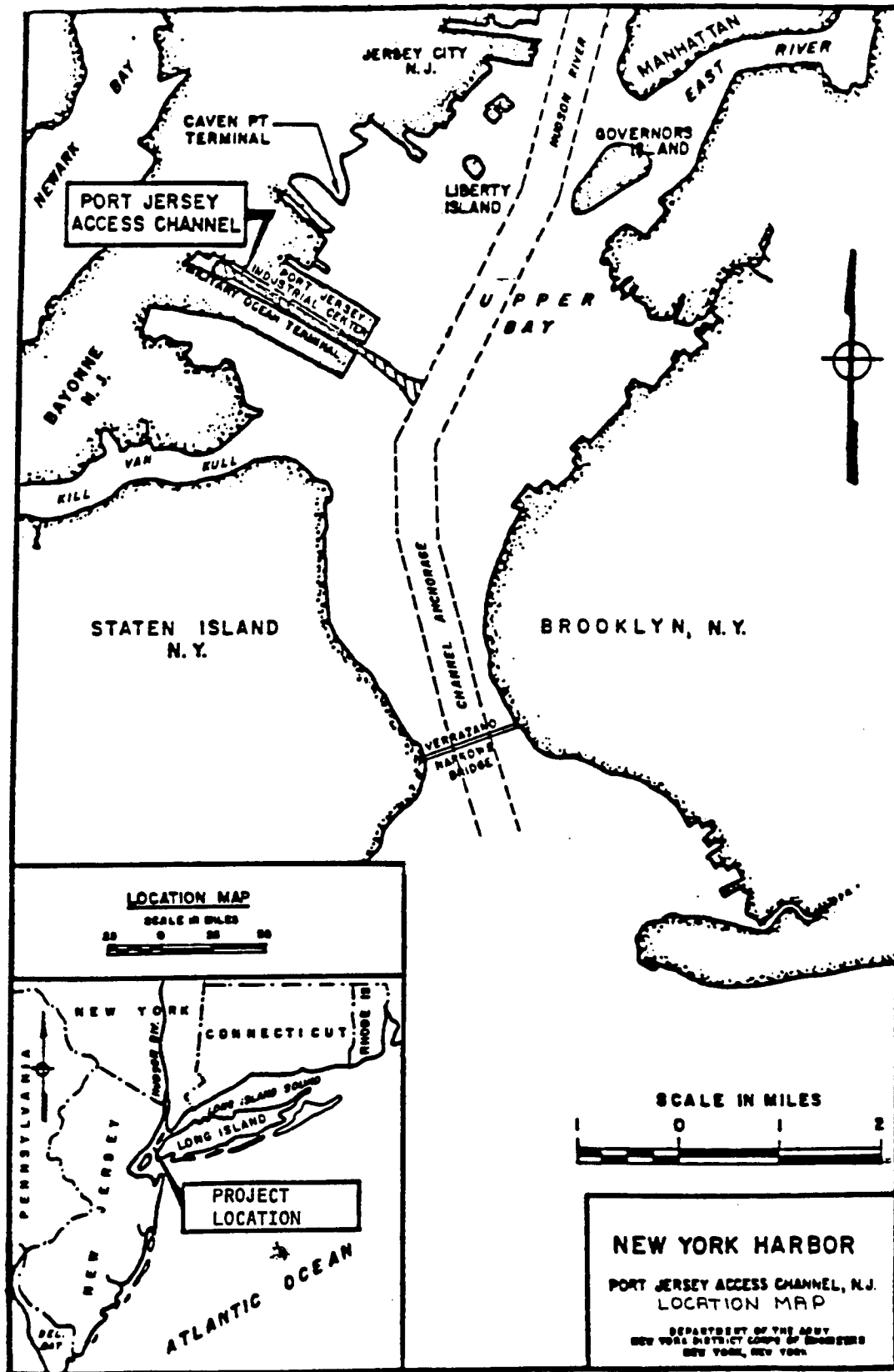


Figure 1. Location and vicinity map

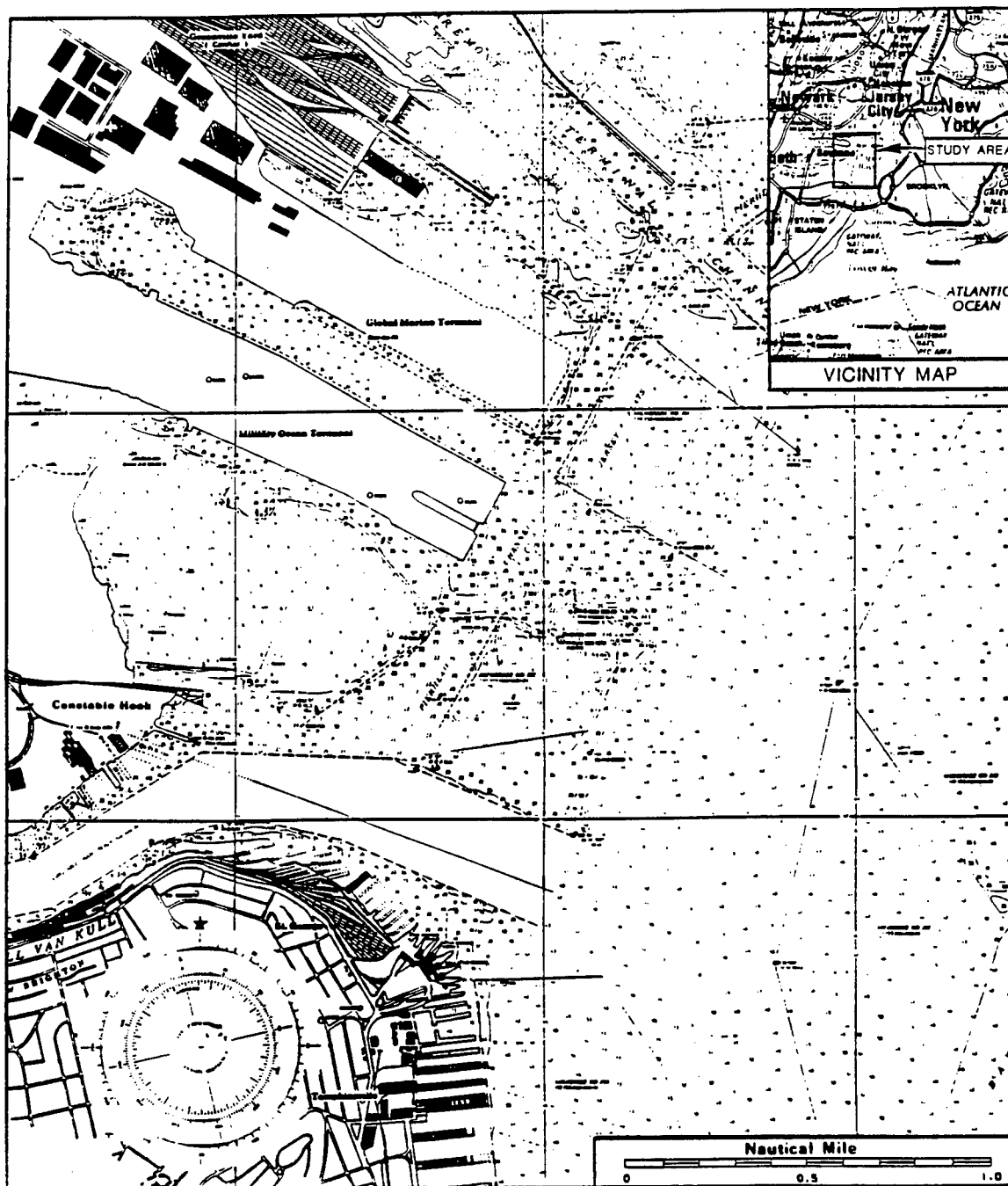


Figure 2. Study area

Wind data indicate prevailing winds over the study area are from the west-northwest direction in the winter and from the south-southwest direction in the summer. Annual average wind speed is 10.2 miles per hour, with calm winds occurring 2.9% of the time. Waves affecting the project site are primarily wind generated waves. The critical fetch for the upper bay is from the south-southeast through the Narrows into the lower bay. From the available wind data taken at Newark Airport, winds greater than 15 MPH from that direction occur less than 0.1% of the time. A 15 MPH from the SSE would generate a maximum 1.5 ft wave. These waves are negligible in the project area.

National Ocean Survey (NOS) maintains two reference tide gauge stations; one at Sandy Hook and the other at the Battery for which long term records of the tides are available. The tide at Sandy Hook is semi-diurnal with two complete tide cycles in approximately one lunar day (24.84 hours). At Sandy Hook the mean tidal range is 4.7 ft, while for spring tides the mean range is 5.6 ft. At the Battery, the mean tidal range is 4.6 ft, while for spring tides the mean range is 5.4 ft. The mean tide range in the vicinity of the Port Jersey Channel is 4.5 ft with spring tides at 5.4 ft. The tidal currents undergo a cycle consisting of slack before ebb, ebb currents, slack before flood, and then flood currents directed approximately opposite to the ebb direction. Daily predictions of the magnitude and time of peak ebb and flood currents and times of slack water at the Narrows are provided by NOS Tidal Currents Tables. Current speed and direction at other locations in the Harbor at hourly intervals within a tidal cycle can be obtained from the NOS Tidal Current Charts for New York Harbor. The greatest current velocities in the study area are the Narrows, and 2.6 knots opposite Port Jersey.

Proposed Channel Improvements

The recommended plan outlined in the feasibility study which is the National Economic Development (NED) plan provides for a channel at a depth of 41 foot below mean low water (MLW) with a channel width of generally 300 ft (USAED 1987). The northern limit of the proposed channel will be 110 ft from and parallel to the GMT bulkhead. The southern limit of the channel will be approximately 340 ft from the MOT bulkhead. At the western end of the channel, in the vicinity of the GMT bulkhead, a widening of the channel alignment is provided from the straight channel section to the turning basin to provide safe access to the turning basin. The width of the channel varies in this location from 300 ft at the eastern end of the GMT bulkhead to 570 ft at the turning basin. The outer channel is 300 ft wide from the main bend to a point 1,000 ft from the end of the channel where it begins to widen to a width of 1,140 ft perpendicular to the east end of the channel. The total project channel length is 9,690 ft plus a turning basin. The turning basin at the west end of the Port Jersey Channel will be 1,200 ft in diameter (see Figure 3).

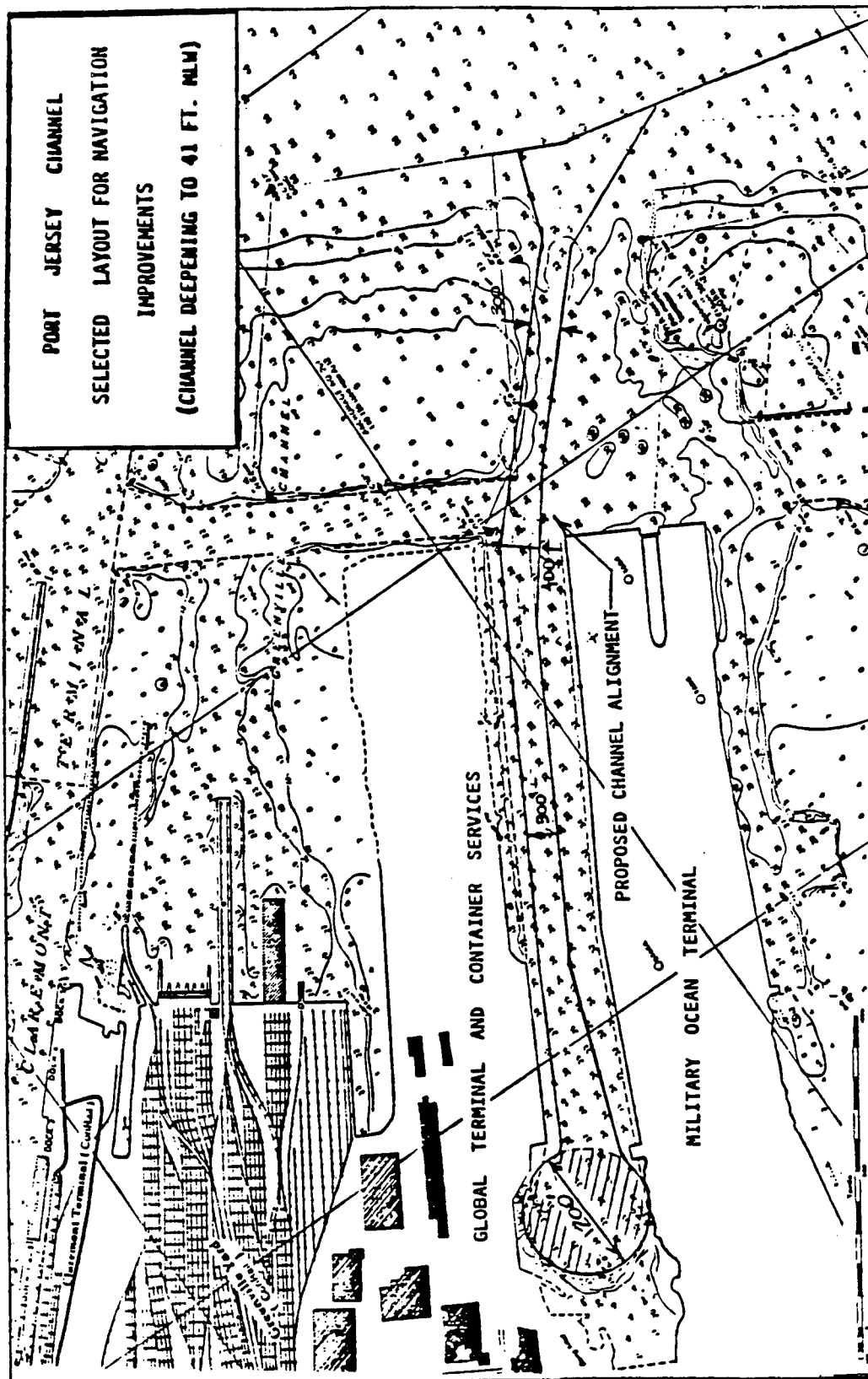


Figure 3. Existing channel

Purpose and Scope of Investigation

The purpose of the ship simulation study was to determine the effect of deepening the Port Jersey Channel. It also aided in the selection of the dimensions and alignment of the recommended channel improvements. This was accomplished by assessing the impacts of the proposed channel improvements on the safety and efficiency of the deep-draft waterborne commerce within the study area.

2 Data Development

In order to simulate the study area, it is necessary to develop information relative to five types of input data as follows:

- a.* Channel database contains dimensions for the existing channel modifications. It includes the channel cross-sections, slope angle, overbank depth, and autopilot track line definition.
- b.* Visual Scene database which is composed of principle features of the simulated area, including the aids-to-navigation, buildings, and loading facilities.
- c.* Radar database contains the features for the plan view of the study area.
- d.* Ship data file contains characteristics and hydrodynamic coefficients for the test vessels.
- e.* Current pattern data in the channel include the magnitude and direction of the current for each cross-section defined in the channel database.

Channel

The information used to develop the channel database came from the District - furnished hydrographic survey charts and NOAA No. 12334. This was the latest information available concerning the dimensions of the channel. New Jersey planar coordinates as shown on the annual survey were used for the definition of the data.

The simulated Port Jersey Channel, which begins 2 miles north of the Varazano Narrows Bridge, has 30 cross-sections. Figure 4 shows the defined channel for the existing condition. Cross-section A was defined in Anchorage Channel, cross-section B was placed between the two shoals, identified by hatch marks on the north and south of the channel (see Figure 4), and cross-section C is located in the area confined by MOT and GMT. Figures 5, 6, and 7 present the lay-out of cross-sections A, B, and C, respectively, as

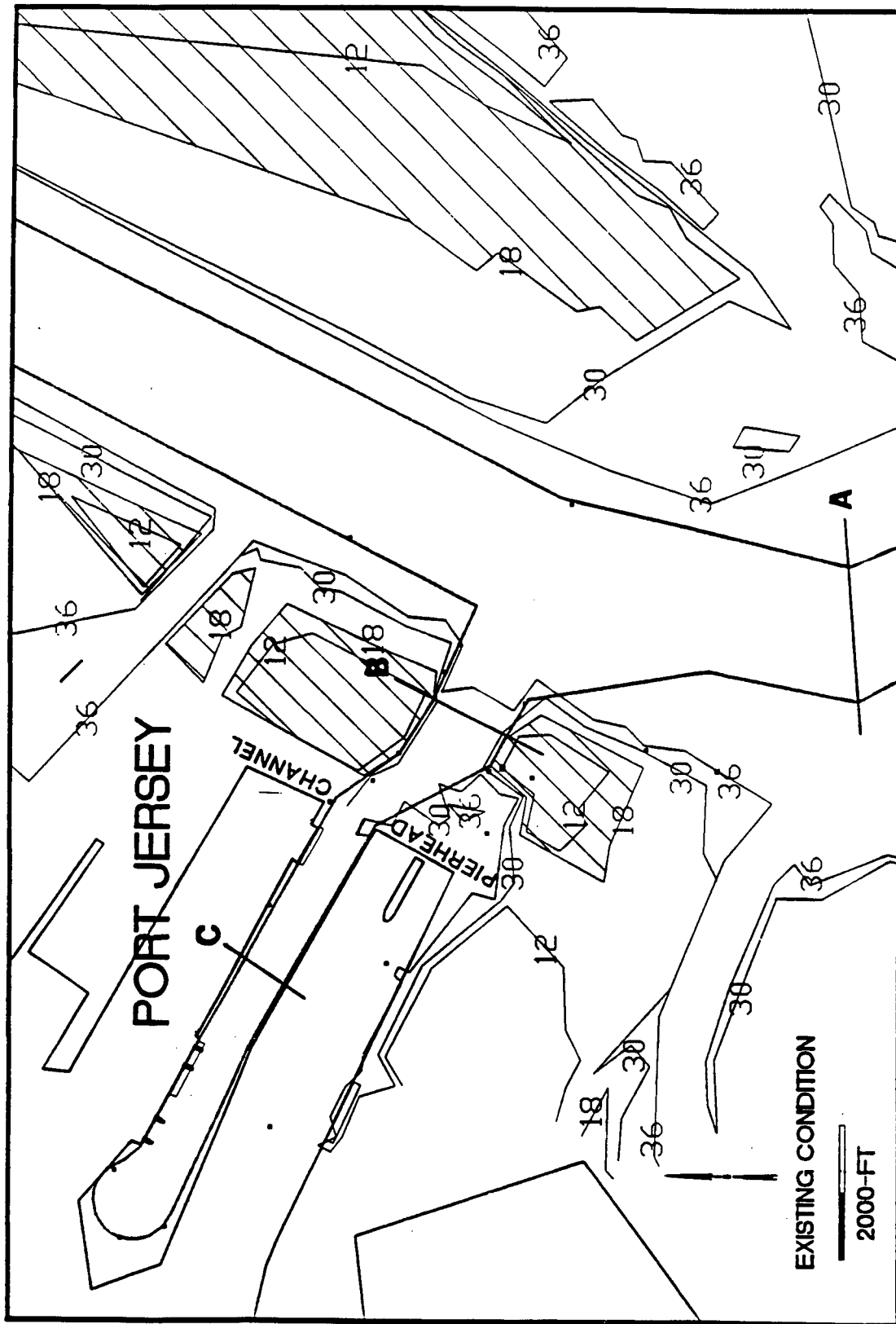


Figure 4. Existing condition

CROSS SECTION A

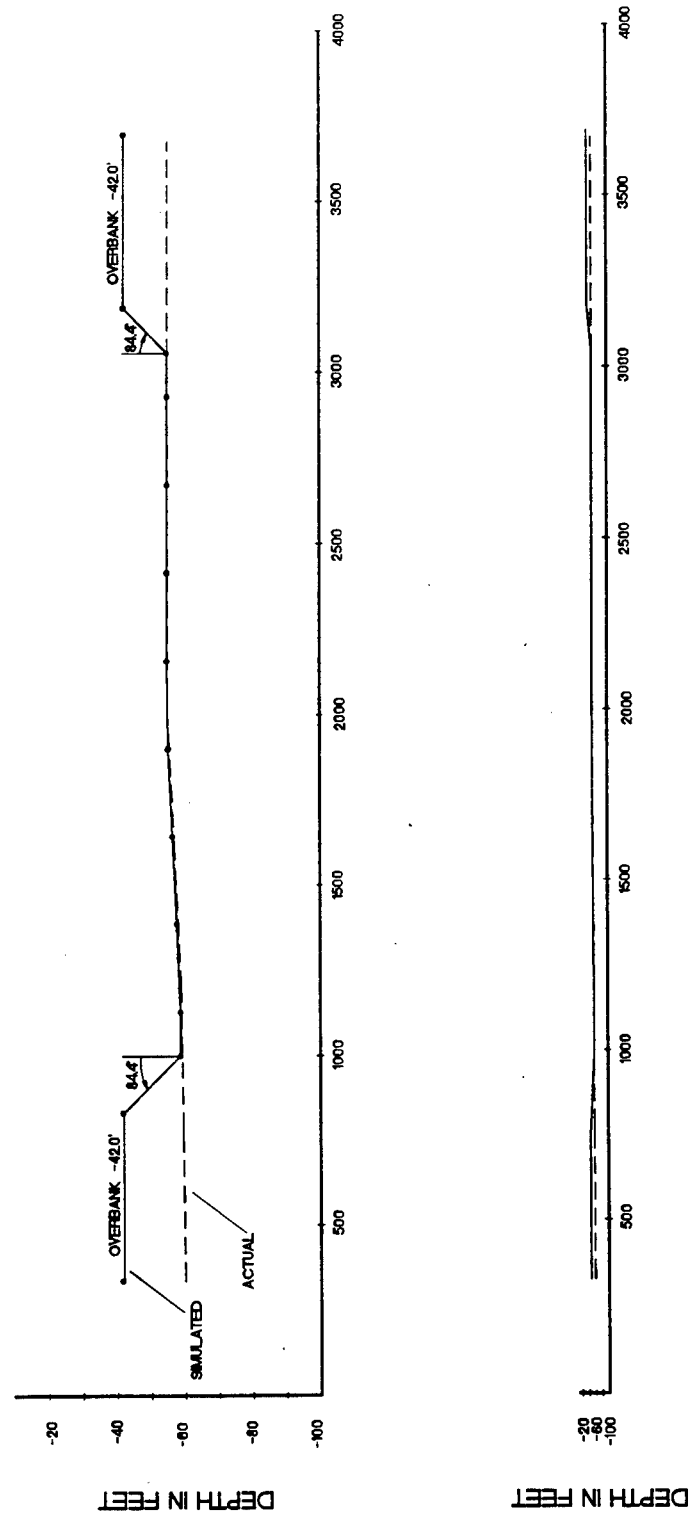


Figure 5. Cross Section A from Figure 4

CROSS SECTION B

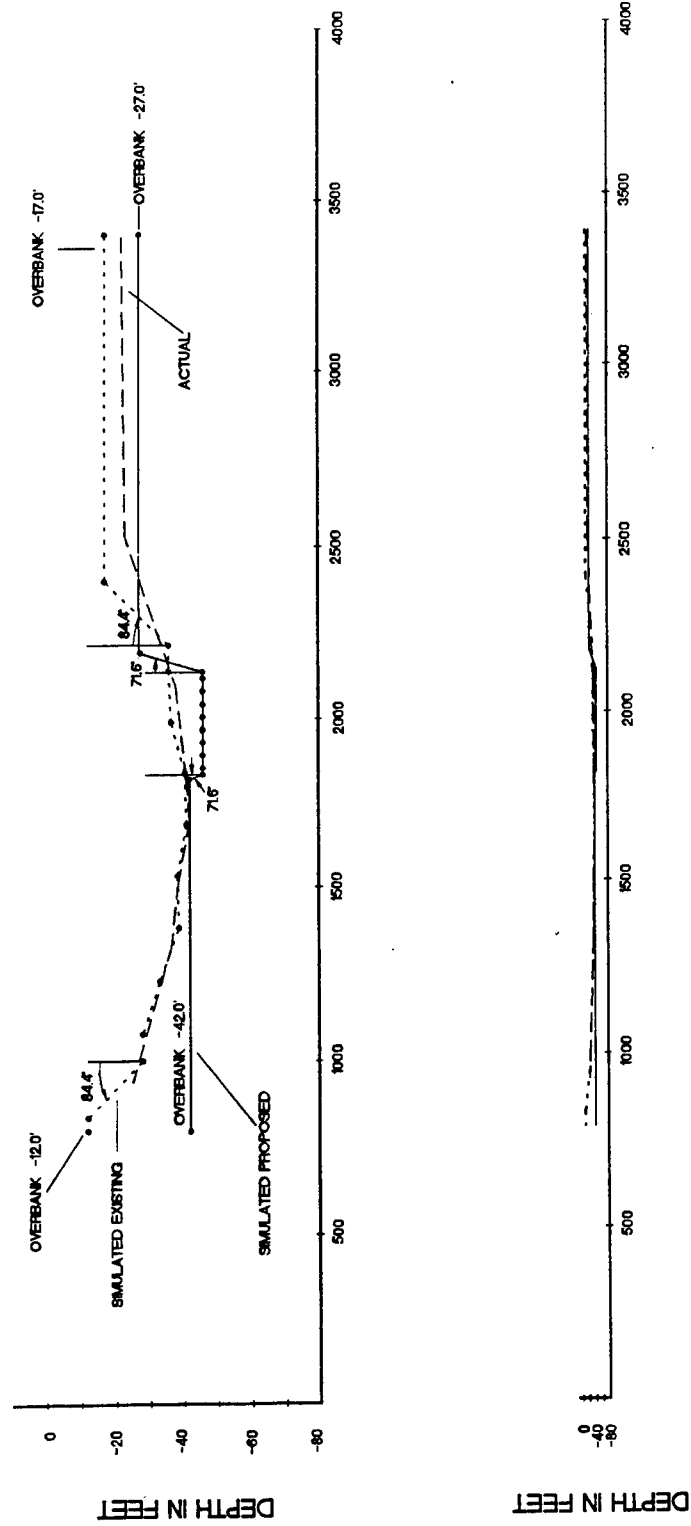


Figure 6. Cross Section B from Figure 4

CROSS SECTION C

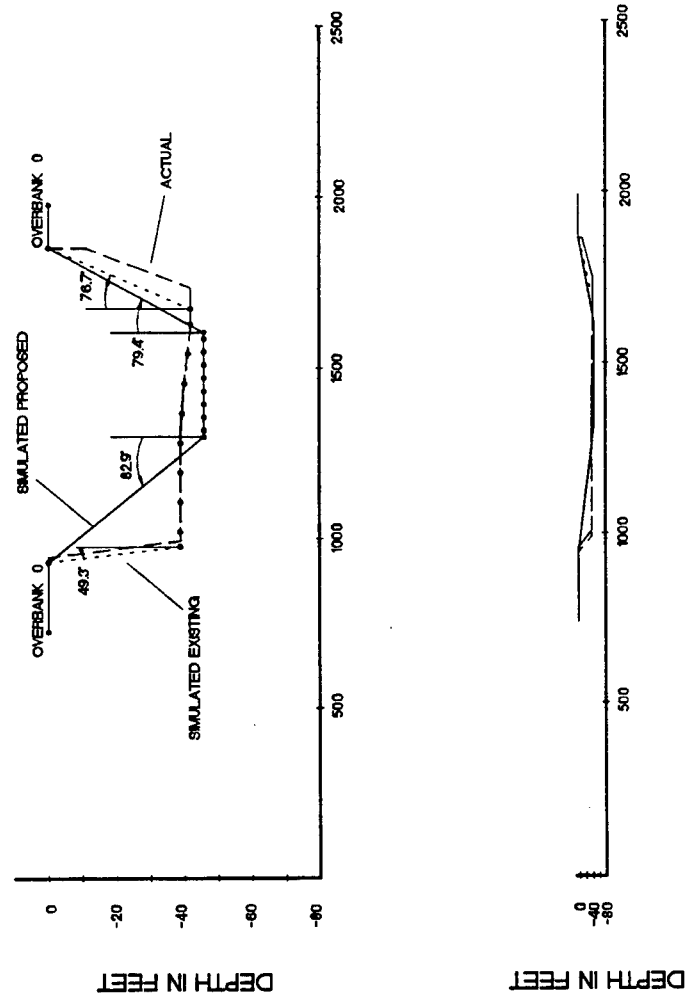


Figure 7. Cross Section C from Figure 4

examples of the cross-section definitions used in this study. The upper plot is exaggerated vertically to show the differences between the simulated and the actual channel cross sections.

Channel cross sections were placed at each bend in the channel and at each surveyed cross section. The ship simulator model allows eight equally spaced points to define each cross-section. At each of these points, a current magnitude and direction as well as a depth are required. These data were extracted from the output of the mathematical model study (Ankudinov 1989). For each cross section, the width, right and left bank slopes and overbank depth are required. These data were obtained from the hydrographic survey data provided by the New York District for use in the main program for calculating bank suction forces. Figures 5, 6, and 7 show the eight points, the bank slopes, and the overbank depths for cross-sections A, B, and C, respectively. It should be noted that even though the actual cross section for A and B have a bank slope of almost 90 deg, an angle of 84.4 deg was inserted into the channel definition. This is because the ship simulation model does not calculate bank forces for an angle of 84.5 deg or greater, which exaggerates the opposite bank force if it exists. To correct for this a maximum of 84.4 deg for bank slope was used for this study. For the proposed cross section B an angle of 71.6 deg was used because this approximates the agreed bank slopes of 3:1 for the proposed channels. For cross section C less severe bank slopes were used because the overbank depth of 0 was the most critical factor. If the 3:1 slope or 71.6 deg was used the banks would be moved closer to the channel edge. Since this would create an excessive bank force the true angle from the channel edge to the top of the bank was used.

Visual Scene

The visual scene database was created from the same maps and chart noted in the discussion of the channel source. Aerial photographs, still photographs, and pilot's comments obtained aboard a transiting ship during a reconnaissance trip to Port Jersey constitute another source of information for the scene. These allowed inclusion of the significant physical features the pilots use for informal ranges and location sightings.

All aids-to-navigation such as buoys, channel markers, docks, buildings, and tanks were included in the visual scene. The information required generating the visual scene in three dimensions: north-south, east-west, and vertical elevation. Again the state planar coordinate system was used. As the ship progresses through the channel, the three dimensional picture is constantly transformed into a two dimensional perspective graphic image representing the relative size of the objects in the scene as a function of the vessel's position and orientation and the relative direction and position on the bridge for viewing. The graphics hardware used for the Port Jersey project is a stand alone computer (Silicon Graphics - Iris 2300) which is connected to the main computer to obtain information for updating the viewing position and

orientation of the ship. Also the viewing angle is passed to the graphics computer for the look-around feature on the simulator console which enables the pilots to look at objects outside of the straight ahead view which encompasses only a forty degree arc. This feature simulates the pilot's ability to see any object with a turn of his head. The pilot's position on the bridge can also be changed from the center of the bridge to the edge of the ship at the bridge wing or anywhere in between to obtain a better view.

It may be noted that the creating of a scenario for the project area is very demanding in terms of engineering judgement. The goal of the scenario is to provide all the required data without excessive visual clutter, bearing in mind the finite memory storage and computational resources available on the minicomputer.

Radar

The radar database is used by the Geneisco graphic image generator to create a simulated radar for use by the test pilots. The radar database contains X and Y coordinates which define the border between land and water. The file also contains coordinates for any major physical feature deemed important such as buildings, bridges, tanks, docks and aids-to-navigation. In short, these data define what a pilot would actually see on a shipboard radar. The radar image is a continuously updated view of the vessel's position relative to the surrounding area. Three different scales were programmed in order for the pilot to choose which scale he preferred.

Current

A current database contains current magnitude and direction at eight points across the channel at each of the cross sections defined in the channel.

Current data used in the simulation were obtained from a TABS-2 mathematical current model which was developed at WES. A detailed report will be published based on the current model study (Brown, et.al.). This model was adjusted to surface current data obtained from the physical model of the WES New York Harbor using mean tidal conditions. The model was then rerun to obtain data on spring tidal conditions. According to the pilots consulted, the maximum flood and maximum ebb conditions are both difficult in the prototype. Due to time limitations, the maximum flood condition was chosen for testing because it was considered to be the most critical. Also, due to the present draft limitation with the existing condition, ships enter with the maximum possible load during high tide, which in this particular instance corresponds to flood conditions. Figures 8 and 9 show the current data obtained from the mathematical model in the study area and the corresponding current data implemented by the simulator, respectively. Figure 10 shows a

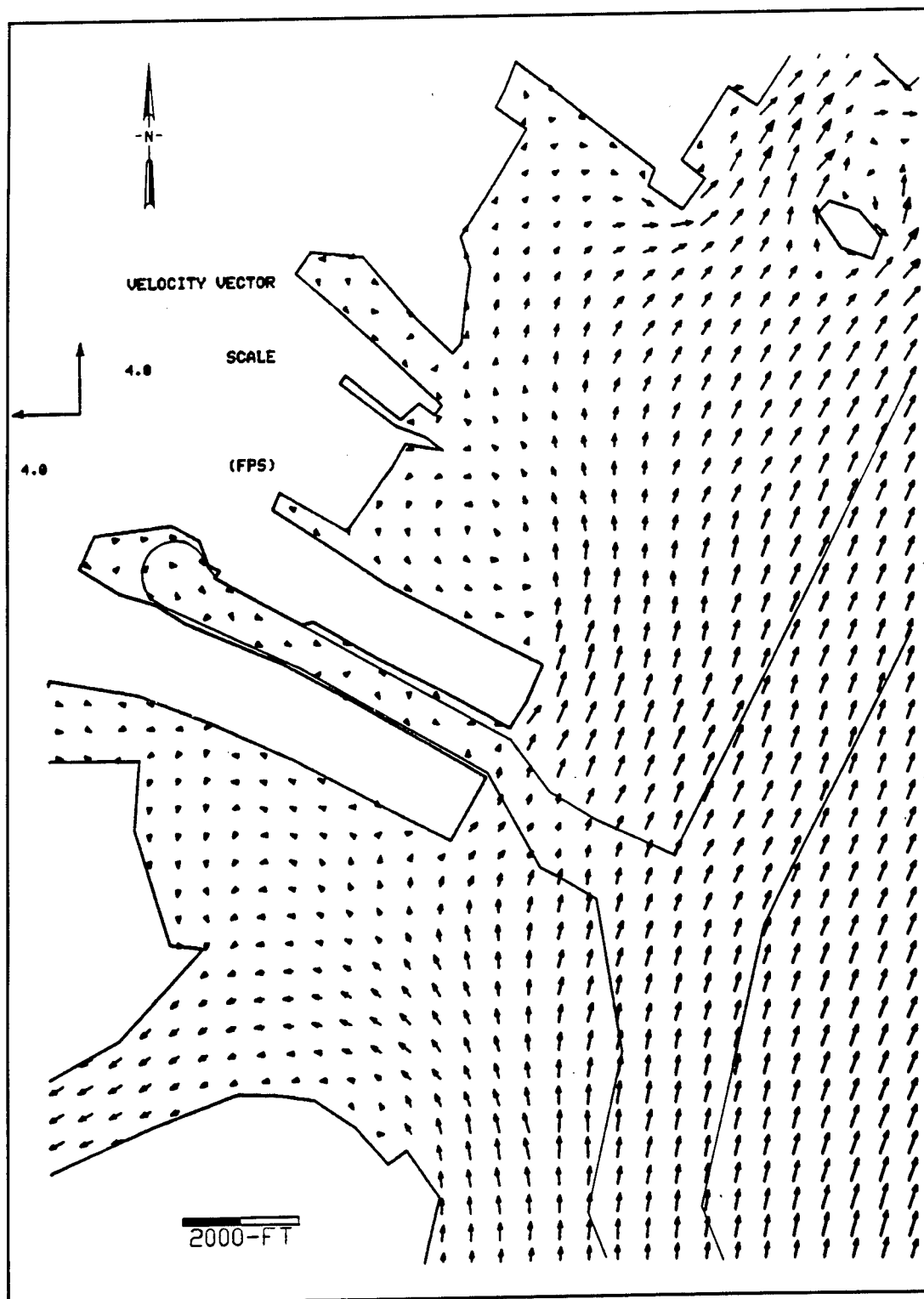


Figure 8. Study area current pattern

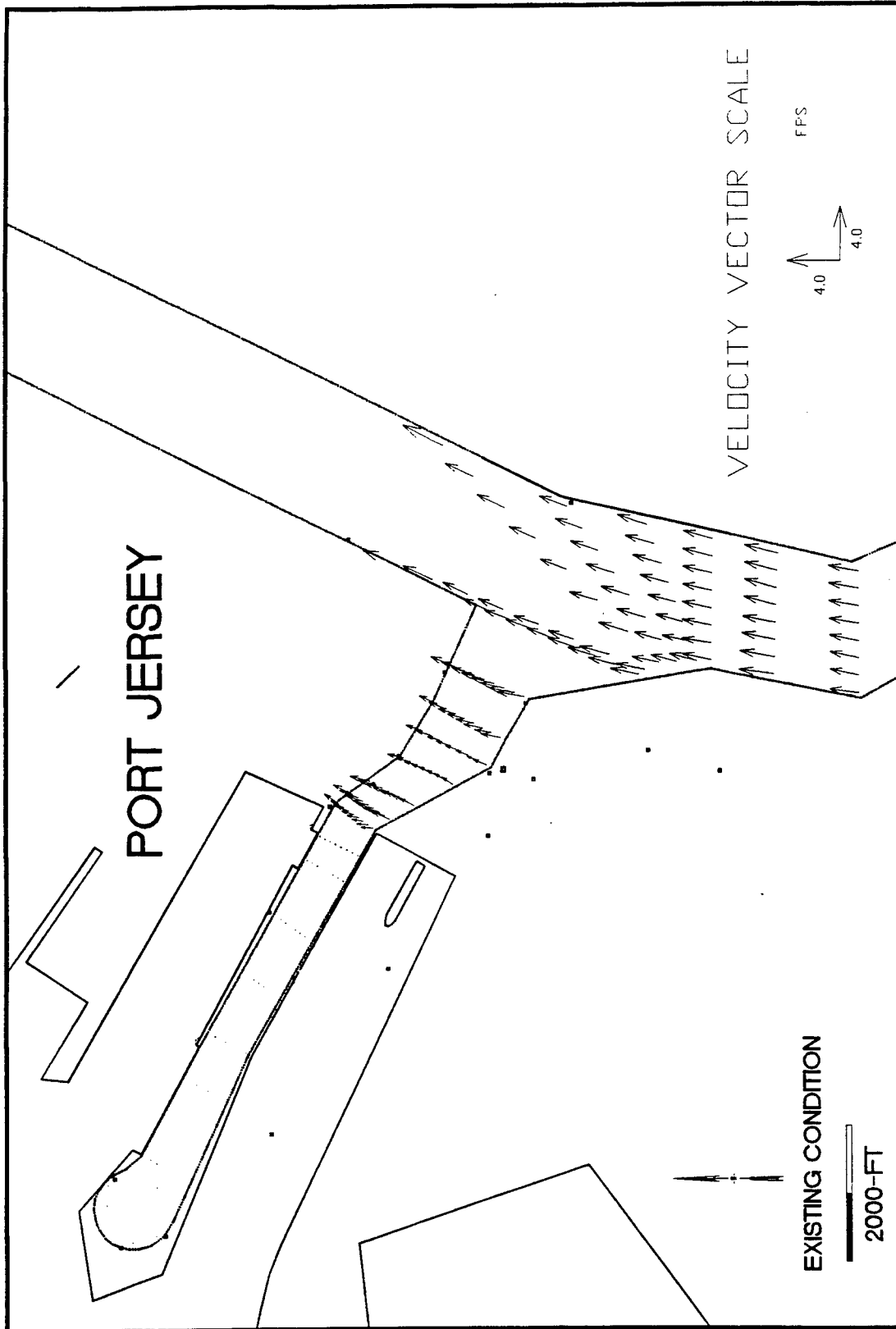


Figure 9. Simulator current data

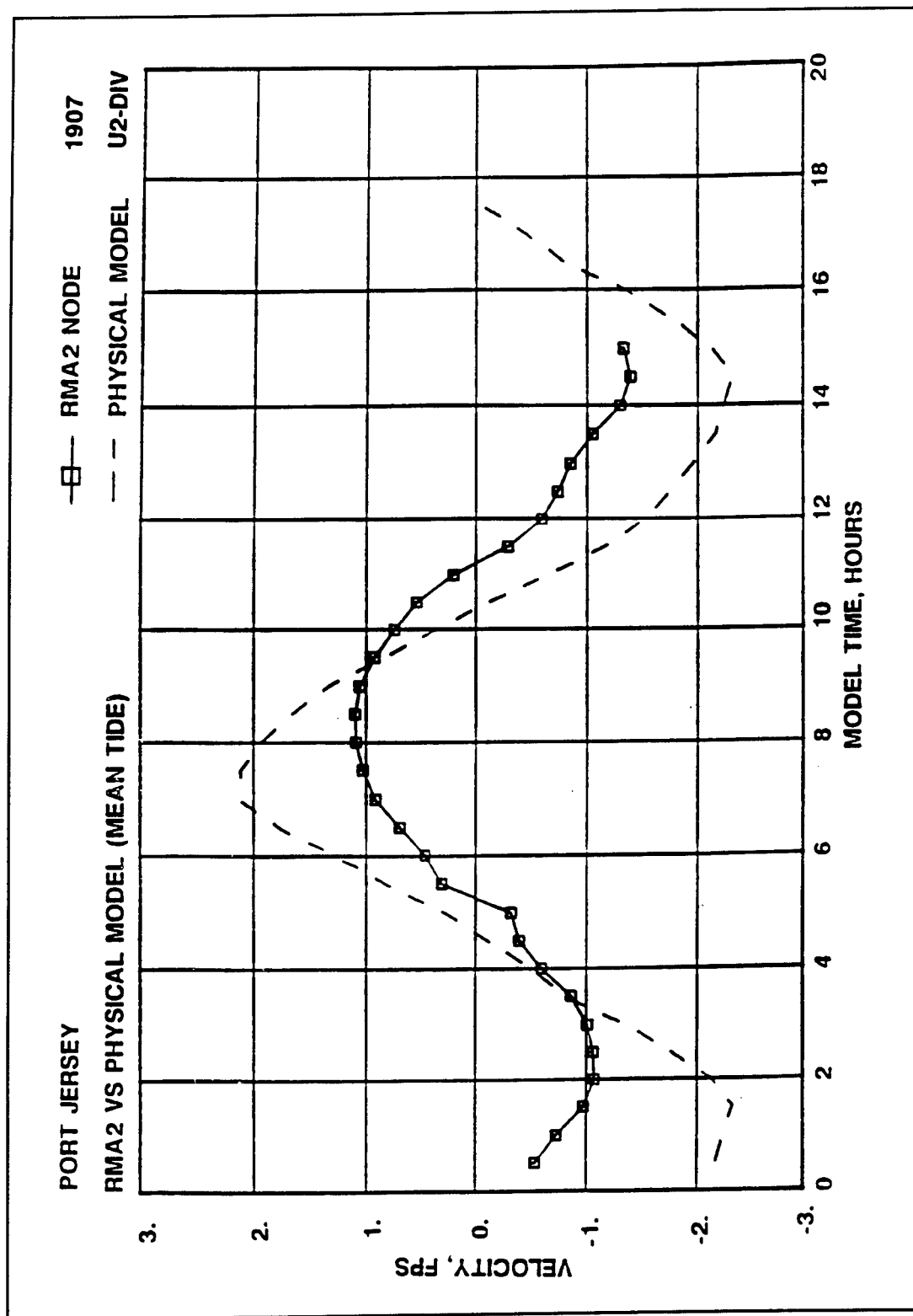


Figure 10. Comparison of RMA2 model output with physical model data

plot of velocity versus time for a point in Anchorage Channel within the study limits. Plots of this type are used to validate the mathematical model using an existing physical model. The physical model data at this point appears to be approximately two times that of the mathematical model.

Test Ship

The ship database consists of the ship characteristics and coefficients used in the hydrodynamic program for calculating forces on the containerships used in the testing program. In addition, the bow of the ship would also be seen in the visual scene by the pilot from the ship bridge. Therefore, a visual image of the ship bow had to be created.

Two ships were used in the simulations. The existing traffic was represented by a Panamax vessel that is 850-ft long overall by 106-ft wide. This ship was loaded to a 35-ft draft since it would be entering on a maximum flood tide. This ship already existed in the WES Ship Simulator fleet of ships and been tested on several projects prior to this one. A description of this ship model can be obtained from Tracor Hydronautics Technical Report 83009-2 (Ankudinov and Barr 1989). The ship used for the proposed channel was an Econ class Panamax container ship that is 950-ft long overall with a beam of 106 ft also. This ship was loaded to the design depth of 38 ft. A contract was made with Tracor Hydronautics to provide WES with the coefficients of this ship and documentation on this is presented in Technical Report 87005.08 (Ankudinov 1989).

3 Navigation Study

Validation Tests

For the purpose of validating the simulation of Port Jersey Channel, a pilot from Turecamo Towing Company who assists in these ships entering this channel visited the ship simulator prior to the actual testing. The purpose of the validation test was to verify and adjust, as necessary, model parameters such as tidal currents, bank effects, wind, ship coefficients and objects in the visual scene based on the pilot's experience and familiarity with the study area.

The validation pilot was very familiar with ship simulations and said that the visual scene of the Port Jersey Channel was the most complete he had seen during initial verification. He did, however, suggest that the dock color be changed so that they were more easily recognized. A significant problem that was noticed almost immediately by the pilot was the inaccurate currents. This was actually an error in the channel definition which caused the currents to act at inappropriate locations. The pilot commented on the efficiency of making the necessary correction.

During validation, the pilot did not feel that the flood currents in the simulation were as strong as he normally experienced. When the current magnitudes were increased by 2.75 times, he felt that these represented a very strong flood tide current that could be reasonably expected to occur. This would make the current velocities somewhat greater than those obtained in the physical model as shown on Figure 10, the plot of velocity versus time for a point in Anchorage Channel within the study limits. The pilot tended to use this area to evaluate the currents.

The wind speed was adjusted several times and it was determined that test runs would be made with a 25 knot wind from the South. When the validation pilot was pleased with the reality of the simulation, test runs were initiated. Runs made by the validation pilot which were determined to be comparable to the other test runs were labeled pilot "R" and used in the data analysis.

Test Conditions

The Port Jersey Channel scenario as implemented on the Waterways Experiment Station (WES) Ship Simulator begins two miles north of the Varazano Narrows Bridge continuing on through Anchorage Channel to its intersection with the Port Jersey Channel, into the Port Jersey Channel until it ends at the turning basin. Anchorage Channel is approximately 2,000-ft wide with naturally deep water extending far beyond the channel limits to shoal areas. Port Jersey Channel is at a 90-deg angle to the main Anchorage Channel; however, because of the naturally deep water the pilots are able to alter their course and thus lessen the degree of turn. The channel passes between two shoals, Jersey Flats and Robbins Reef. A "dog-leg" connects this part of the channel to the channel portion which is protected from tidal currents by MOT and GMT. The channel continues on a generally straight course into the turning basin.

The pilot testing was conducted with several widths and alignments which are shown in Figures 11 and 12. They all begin at the Anchorage Channel with a flare of approximately 1,000 ft tapering to a narrow channel with a 12.5 deg widened turn at the terminal. The channel then proceeds along the north side of the existing channel between the terminals until a flare into the turning basin opposite the GMT Pier. The turning basin is unchanged except for the flared entrance. The channels along the Global Marine Terminal are 250-ft, 300-ft, 370-ft, and 440-ft wide. The approach channels are 300-ft and 370-ft wide or tapered from the turn at the northern boundary, which is 110 ft from and parallel to the GMT. It should be noted that southern edges of the channel are to the north since it serves the GMT. It will be seen later that this produces some problems because the pilots prefer to stay as far as possible from each bank. This strategy would put them at this centerline which is near or outside the channel boundary in some of the alternative channels.

The simulation study was designed to test each of the channel alternatives for comparison with the existing conditions. Plate 1 shows the combinations of proposed channel alignments that were tested. The existing condition as simulated is shown in inset I. Inset II shows the test conditions for the 250-ft channel between the terminal with a 300-ft wide approach channel. This is called the 250-ft test channel. Inset III shows the 300-ft wide channel both between the terminals and the approach channel. This is the channel design recommended in the project's feasibility study. A 370-ft wide channel in both segments is presented in inset IV. Finally, the 440-ft channel is shown in inset V. This test condition had a 440-ft wide channel between the terminals with a tapered approach channel as shown in Figure 11. The short range aids-to-navigation were adjusted for each condition. Buoys were placed to mark corners and, since the channel was to offset to the north from the center of the existing channel, ranges were provided in the simulation to guide the pilots in aligning on the deepened channel centerline. One of these ranges is shown on the west end of the turning basin; the other is outside the area shown on this plot.

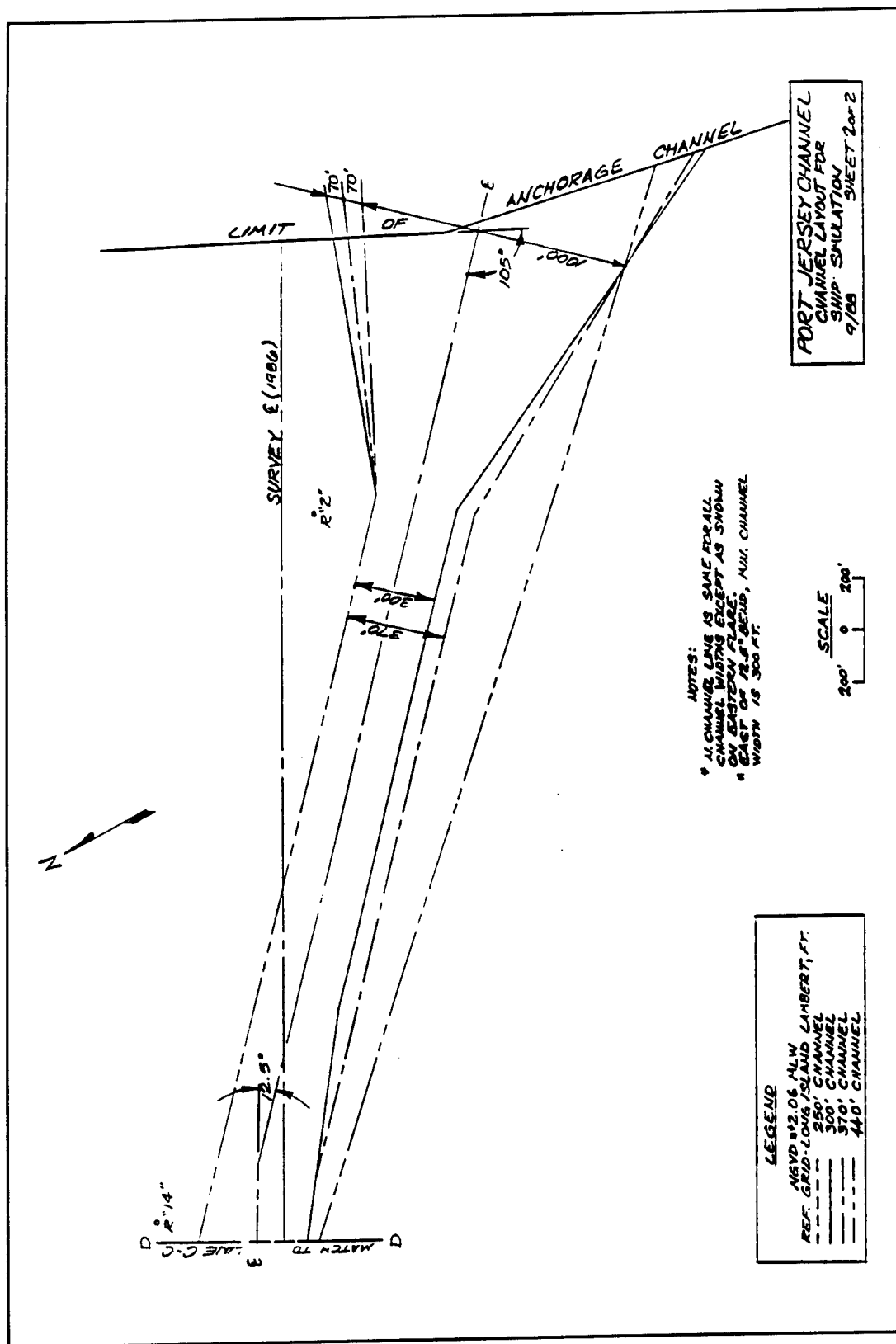


Figure 11. Channel alignment and widths, seaward section

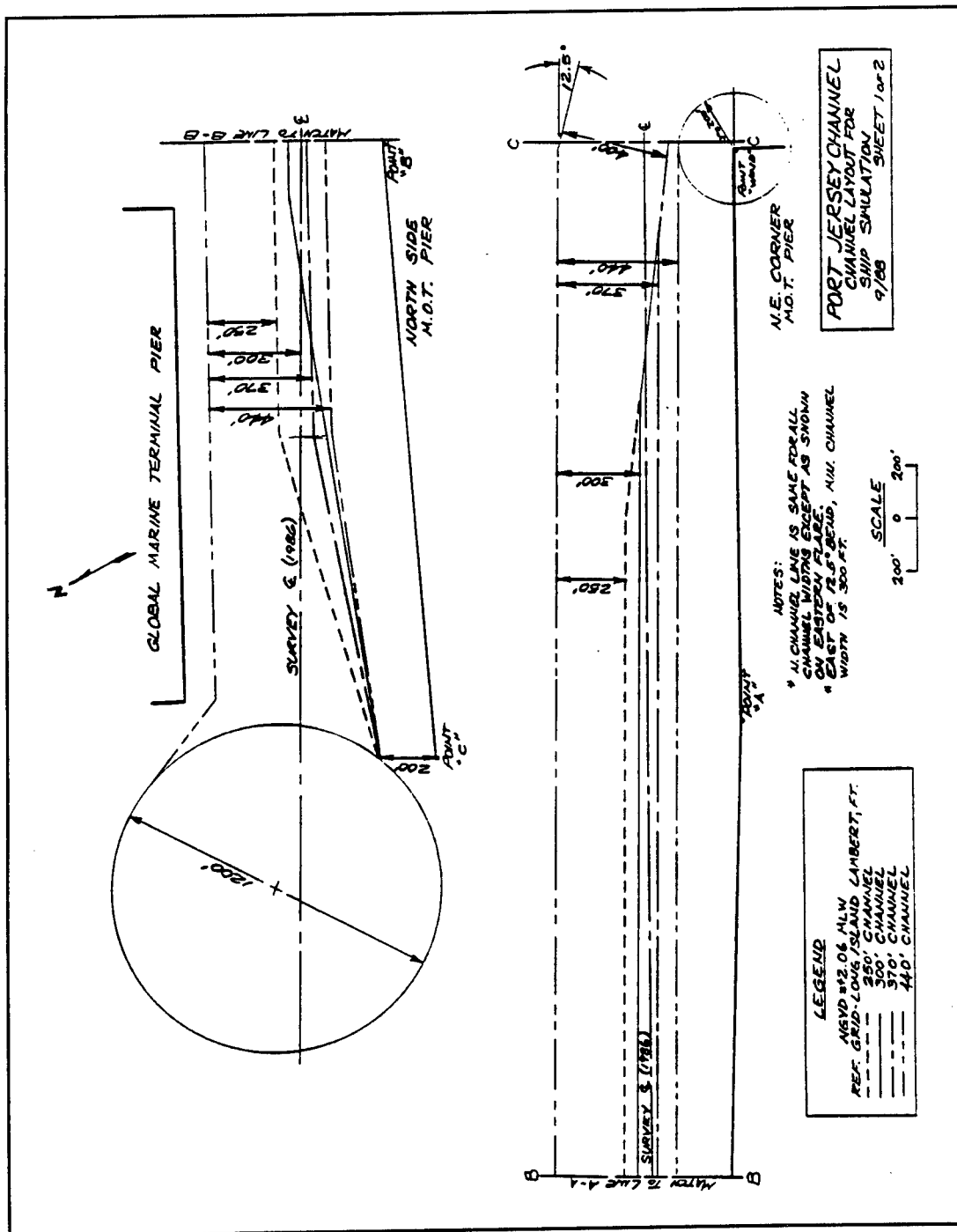


Figure 12. Channel alignments and widths, inside section

Two ships were used in the simulations. The existing traffic was represented by a Panamax vessel that is 850-ft long overall by 106-ft wide. This ship was loaded to a 35-ft draft since it would be entering on a maximum flood tide. The ship used for the proposed channel was an Econ class Panamax container ship that is 950-ft long overall with a beam of 106 ft also. This ship was loaded to the design depth of 38 ft. A small number of tests were run with the 850-ft-long ship in the proposed 300-ft wide channel as an indication of how the vessel currently using the channel would behave in the improved condition. During maneuvering, the pilots were aided by up to five 4,000 hp tugs which were used at their discretion.

Current data used in the simulation were obtained from a TABS-2 mathematical current model which was developed at WES (Brown, et.al.). Current data were discussed in the previous chapter.

Since the ships that use this channel are primarily containerships, they are affected by wind. Therefore, all tests were run with a 25-knot wind from the South. This South wind will aggravate the difficulty of ship handling in the flood currents and also tends to make ship handling within the terminal area riskier with the presence of moored ships to the north.

Twelve combinations of conditions were tested. These combinations are listed in Table 1. Inbound runs started from the Anchorage Channel with a heading of 345 deg and proceeded into Port Jersey Access Channel to the turning basin, turned in the turning basin and docked at the Global terminal port-side-to, i.e. the bow is pointed to the east. The outbound runs were primarily initiated starboard-to with the bow pointing to the turning basin at a heading of 300 deg, backing out all the way to Anchorage Channel and turning out in naturally deep water. These conditions were run with all test channels. An additional outbound run was conducted with the 300-ft channel in which the ship was started docked port-to with the bow pointed outbound, heading of 120 deg, so that the exit would simply involve steering the turns. This would be the condition if the ship had turned on entry to the channel.

Both inbound and outbound runs of the existing channel used the 850-ft containership with a 35-ft draft. The proposed channel alignments were run with the 950-ft containership with a 38-ft draft. These runs were agreed to be the necessary test runs during the meeting involving WES, District personnel, and a local harbor pilot held on 4 October 1988. An additional inbound run was made in the 300-ft proposed channel with the 850-ft vessel. This was to demonstrate the difficulty, if any, of using the longer, deeper ship.

Since pilot test hours were limited, an early decision, based on pilot testimony and performance during validation, was made to concentrate on the 300-, 370-, and 440-ft alternatives. These test conditions were executed in random order that did not allow learning to operate the simulator to be a biasing factor i.e. the order was different for each pilot and did not progress in the same order through the different size channels. However, the 250-ft channel as well as the 300-ft channel width navigating the 850-ft vessel instead

of the 950-ft vessel was run only if time allowed. This process biased the results in that the pilots who adapted well to the simulator were the ones who made runs of the latter two conditions. In addition, they did these runs after considerable practice with the simulator. Therefore, these run results must be carefully evaluated compared to the other run conditions.

Test Procedure

Six professional pilots participated in the testing program. Three pilots were tug masters from Turecamo Towing. Two pilots were tug masters from Moran Towing. The final pilot was from the Sandy Hook Pilot Association. The latter pilot brings large containerships into these terminals less frequently than others. The seventh pilot, "R", was the validation pilot. He was also from Turecamo Towing. Some of his runs were determined to be comparable to the other test runs and these were used in the data analysis. The purpose of the testing was to determine the effect of the deepening and narrowing plans for the Port Jersey Channel on ship handling. By involving the local professional pilots, their skill, experience and familiarity with handling ships in the area were incorporated in this evaluation. The pilots were briefed on the study and introduced to the equipment after which they conducted familiarization runs in the simulated existing channel before they started the actual testing. A total of 103 runs were made. A complete list of test runs is presented on the table below.

| Port Jersey Ship Simulation Study Test Conditions | | | | | | | | | | | |
|---|--------------------|-----------------|------------------|--------------------------|---|---|---|---|---|---|-------------------------------|
| Test Condition | Channel Width (ft) | Ship Transit | Ship Length (ft) | Number of Test Per Pilot | | | | | | | |
| | | | | A | B | C | D | E | F | R | Number of tests per condition |
| 1 | Existing | Inbound | 850 | 2 | 2 | 2 | 2 | 1 | 2 | 1 | 12 |
| 2 | | Outbound Astern | 850 | 1 | 2 | 1 | 2 | 1 | 1 | 1 | 9 |
| 3 | 250 | Inbound | 950 | 1 | 0 | 0 | 1 | 0 | 1 | 3 | 6 |
| 4 | | Outbound Astern | 950 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 5 | 300 | Inbound | 850 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 5 |
| 6 | | Inbound | 950 | 2 | 2 | 3 | 2 | 0 | 2 | 1 | 12 |
| 7 | | Outbound Ahead | 950 | 2 | 1 | 2 | 2 | 1 | 2 | 1 | 11 |
| 8 | | Outbound Astern | 950 | 1 | 2 | 2 | 1 | 0 | 1 | 1 | 8 |
| 9 | 370 | Inbound | 950 | 2 | 2 | 2 | 2 | 1 | 2 | 0 | 11 |
| 10 | | Outbound Astern | 950 | 1 | 2 | 1 | 1 | 1 | 2 | 0 | 8 |
| 11 | 440 | Inbound | 950 | 3 | 2 | 2 | 2 | 1 | 2 | 0 | 12 |
| 12 | | Outbound Astern | 950 | 1 | 2 | 1 | 2 | 1 | 1 | 0 | 8 |
| Total Number of Tests | | | | | | | | | | | 103 |
| All tests were made with maximum flood during spring tide and south wind at 25 knots. | | | | | | | | | | | |

Test Results

All tests were conducted by professional pilots. The warm-up runs performed by the pilots were not included in table above or in the test analysis. During each run, the characteristics parameters of the ship were recorded every five seconds. These parameters included the position of the ships center of gravity, speed, rpm of the engine, heading, drift angle, rate-of-turn, rudder angle, port and starboard clearances. Data were also kept on the pilot's use of tugs.

The simulator tests were evaluated based on pilot ratings, ship tracks, and statistical analysis of the various ship control parameters recorded during testing. The following sections will discuss these three evaluation methods.

Pilot's Ratings

To determine what the pilot thought about the simulator and the proposed deepening, two questionnaires were prepared to document their comments and rate the runs. These questionnaires are presented in Appendix A. One was given to the pilots after each run and a final debriefing questionnaire was given after the completion of the final test run. For each run, the pilots were asked to give a rating on the difficulty of run, the danger of grounding, the ability to overcome effects of wind and current, possible damage to docked ships, the controllability in the outer harbor, the controllability in the inner harbor, and the simulator accuracy. The simulator accuracy was given an above average rating by the pilots as shown in Plate 2.

Inbound runs

For the other rating categories a lower rating, indicating a safer channel, was recorded for the inbound runs of the existing condition (see Plate 3). In general, the proposed channels are rated most difficult for the 250-ft channel and progressively easier as the channel widens. The 300-ft channel run with a 850-ft ship was rated lower than with the 950-ft ship. This is consistent with expectations. However, the 370-ft channel was rated lower than the 440-ft channel for overall difficulty of run, controllability in outer harbor, and ability to overcome adverse wind and current.

Outbound runs

The outbound runs show a dramatic trend in which the existing channel and the run which was made driving out instead of backing out show low ratings (see Plate 4). The runs which were made backing out in all proposed conditions were rated much higher. These results are consistent with what is

expected. The 370-ft channel got lower ratings than the 440-ft channel in difficulty of run, damage to docked ships, and effects of wind and current. However, the 370-ft channel scored higher than the 440-ft channel in controllability in outer harbor, in fact, it even got higher ratings than the 300-ft channel run with the 950-ft ship.

Composite Ship Track Plots

Inbound

Existing condition. Plate 5 shows a composite ship track plot of the inbound runs of the existing condition made by all pilots. Appendix B presents the pilot track lines. In the existing channel alignment, vessels entering Port Jersey Access Channel from the Anchorage Channel alter their course from the main shipping channel toward the west at an angle of approximately 45 deg to the current. The turn is initiated as they approach buoy R26. During flood tide, they point the ship toward the north end of the MOT to allow for the drift due to the flood currents. As they approach buoy R4 they must steer to the northwest again using buoy R14 as a guide. Then they must quickly straighten up to align with the terminal portion of the channel. The area from the intersection of the two channels to just past the MOT is a critical section since at this location the pilot is forced to turn his vessel broadside to the maximum flood current. For this reason, this section, area A, was isolated from the area protected from the current, from the MOT to the GMT, area B. These areas are shown in Plate 6. Approaching the MOT, the pilots use the current acting on their stern to align their vessel heading down the center of the channel as they want to keep the maximum distance from the objects on either side of them. Anticipating the 25-knot wind from the south, most pilots moved their vessel to the south edge of the turning basin and rotated clockwise. Only one pilot violated the channel boundary and apparently collided with a portion of the MOT. According to this pilot, he set up on the green buoy, G1, too soon and because of this he did not drift as far north as he anticipated. Plate 7 shows the existing condition inbound runs with this one run removed. It can be seen that the pilots have no problem keeping the ship in the channel under these extreme conditions.

Proposed conditions. All four proposed conditions were run with the 950-ft containership. The proposed channel configuration were more difficult to navigate than the existing alignment. Due to the vessel's increase in draft to 3 ft, which restricted passage to the deepened areas, the masters could no longer alter their course approaching the R26 buoy to reduce the angle between current direction and ship heading. They were required to turn their vessel across the strength of the current for approximately 4,000 ft as compared with slightly over 1,000 ft in the existing condition. This created severe problems in handling the ship compared with the existing conditions.

250-ft channel. The 250-ft channel composite ship track plot of the inbound runs of all pilots is shown in Plate 8. Plate 9 presents the mean minimum port and starboard clearances for area A and area B. The mean minimum clearance shown in these plots is obtained by averaging the minimum clearance value for each run that occurred within each 1,000-ft section of channel, approximately one ship length. This value is plotted in the midsection of the 1,000-ft section. The location of the beginning of the Port Jersey Channel, east end of the MOT, and the beginning of the turning basin are identified to assist in locating relative positions along the course line. The pilots' average minimum clearance is negative throughout much of the channel. This illustrates that the majority of the test runs were beyond the channel limits at these locations. It can be stated from this information that this channel is not sufficient. This supports the previous decision to concentrate on the 300-, 370-, and 440-ft alternatives.

300-ft channel. The pilots did not think the 300-ft channel was adequate and said so in written and oral statements. The composite ship track plot of the inbound 300-ft channel runs is shown in Plate 10. The pilots demonstrated uncertainty in the best strategy to approach this new channel alignment. The pilots' primary strategy was to gain control of the ship crossing the current by increasing the ship's speed. This process appears successful in the area administered but the additional speed, the decreased channel width at the terminal entrance, and the offset of the channel toward the GMT could result in damage to any vessel docked at the car carrier terminal at the east end of the GMT. Also, slowing the ship down after this increase in speed caused one pilot to lose control. This is what the pilot who ran into the docked ship at GMT expressed as the reason for this collision. "The channel is so narrow that you must increase speed until speed is excessive for entering the inner channel." Ships of this size are best controlled when increasing speed: when decreasing speed the pilot cannot anticipate how the ship will react. Slowing the ship down continuously, starting at MOT had a significant enough impact to cause the pilot to lose control of the vessel and collide with the GMT.

One pilot considered the only way to approach the channel was to slow down significantly and use tugs to overcome the current. This was not accomplished successfully because the five tugs were not sufficient to stop the drift and keep the vessel in the channel. This can be dramatically observed in the run that nearly stopped in the Anchorage Channel and then drifted out of control northward. Subsequently, he then continued to have difficulty controlling the ship with the tugs as he had no control from the ship's own power. Plate 11 shows the composite tracks without these two runs. In repetitions of this run this pilot used the strategy of increasing ship speed to overcome the current; however, he stated that he would wait for more favorable conditions. "Channel should be improved to present width. If not, window off approach...docking becomes dependent on slack water and little wind."

Due to these two very different strategies, the 300-ft channel inbound runs with the 950-ft ship have a very large variance in results. Plate 12 shows that

the mean minimum clearances for the 950-ft containership are not acceptable. EM 1110-2-1613 (USAED 1983) states "the minimum width of bank clearance should be 60 percent of the vessel beam." This would coincide with approximately 64 ft in this case. The port clearance in area A is only about 100 ft and the starboard clearance is negative, indicating groundings occurred for most of the ships. In this particular case, 9 of 12 runs grounded on the starboard side of area A. In area B, the mean minimum port clearance is also negative and the starboard clearance is barely over 100 ft.

It can be seen on the composite ship track plot of the 300-ft channel run with the 850-ft ship with a 35-ft draft (Plate 13) that this ship is much more easily maneuvered through this channel. Plate 14 shows that, with the ship currently being used at this terminal, the pilots do not average a negative starboard clearance in area A or a negative port clearance in area B. However, it must be pointed out that this set of runs could be biased as discussed previously. For example, if a pilot had bad runs of the 300-, 370-, or 440-ft test conditions, he then reran those runs instead of running the 850-ft ship in the 300-ft channel. This pilot is more likely than the others to have a bad run of this condition; however, since he did not do this run the results show an unusually good channel.

The 370-ft channel. In the 370-ft channel the strategy of slowing down and using tugs to maintain control while crossing the current was not attempted. Plate 15 is a composite ship track plot of the inbound runs for this channel condition. It can also be noted that there still is a wide variance in the transits through the approach channel to the terminals. It can also be noted that even with the wider channel in the terminal area, the pilots still favor the center of the channel as defined by the two terminal edges even though this is the south edge of the channel. This could be due to long habit, concern with the effects of the south wind at slow speeds, and the docked ships at the GMT pier. They do not seem to line up on the ranges provided. One pilot said: "The banks on either side could be used to determine where the deep channel is located." Other pilots expressed that the improved channel should include the center of the existing channel. They seem to want to keep a maximum distance between their ships and the terminals on either side.

A closer look at the approach channel tracklines, area A, is provided in Plate 16. It is observed that there are deviations on both the north and south side of the channel with the excursions on the north side being more serious. There is also a tendency to clip the channel corner near the MOT terminal east end. However, a look at the mean minimum port clearance (Plate 17) indicates that the majority of the transits maintained a 100-ft clearance on the port side until the ship reached the end of the MOT. This means that most of the transits stayed away from the south channel edge; in fact, only 2 out of 11 transits were near or grounded on the south channel edge. These two showed similar traits to the pilot run described above in that they appeared to have turned too soon or too quickly. They had to adjust their heading since the vessel was going toward the MOT and was not drifting northward as they must have anticipated. The north side of the channel was crossed in 6 out of 11 runs as shown by the

negative mean minimum starboard clearance. This indicates that the approach channel is not wide enough.

A similar look at area B tracklines is shown in Plate 18. Plate 17 indicates that there is an average of about 50 ft from the east end of the MOT to about where the ship is moored at the GMT pier. The port clearance then becomes slightly negative, a little over 6 ft. The mean minimum starboard clearance is nearly 200 ft over most of the terminal channel segment once the east end of the MOT is cleared. Again, it is observed that the ships cut the channel corner at the east end of the MOT and continue to transit down the center of the channel with some movement farther south away from the ships moored along the GMT. This is in spite of the fact that the installed ranges attempted to guide the pilots to use the center of the new 370-ft channel. Possible reasons why this is true are given in the paragraph above.

The 440-ft channel. Plate 19 shows the composite ship track plot of the inbound runs of the 440-ft test condition. One transit is observed to be similar to several others noted before, i.e., the pilot turned too sharply and headed straight for the MOT south of the channel. Plate 20 shows the tracklines without this run. Plate 21 shows area A from Plate 20 in more detail. Plate 22 shows that the mean minimum clearances all remain positive with the starboard clearance minimum being 40 ft indicating that the majority of the runs were totally within the channel. The mean minimum port clearances were over 100 ft even at the MOT corner. Plate 23 presents a cumulative percentage of the minimum starboard clearances throughout area A for all runs with the exclusion of the run eliminated above. It can be seen that 13 percent of the run samples throughout the area A were negative. This includes all samples which are time dependent; thus, a slow moving ship can have more data samples included in this average and could bias the results toward its track line clearances. A single ship that gets out of the channel and stays out could be the only track line that influences this statistic. Out of 11 runs, only one run went beyond the north edge of the channel and stayed out. Two runs clipped the corner at the end of the entrance taper on the north side. This in itself is not definitive; however, 13 percent of the samples grounding is not acceptable.

The tracklines in the area B channel (Plate 24) indicate that the channel is adequate with the exception of the inside corner of the turn at the east end of the MOT and opposite the moored ship at the GMT pier. Plate 22 shows that the mean minimum port clearance is over 100 ft as is the starboard clearance. In fact, only one ship track line comes close to the ship at the east end of the GMT and one other grounds on the south side of the channel opposite the ship docked at the west pier. This is based on 12 total runs.

Outbound

Outbound backing. Concern was expressed in the meeting on 4 October 1988, discussed in paragraph 4 on page 10, that the 1,200-ft turning basin

would not be large enough to turn the 950-ft ships. At that time it was determined that an alternative to this operation might be necessary. According to one pilot, backing out of Port Jersey Channel into Anchorage Channel with the assistance of tugs and turning in the Anchorage Channel would be the method preferred by pilots. When interviewed, the pilots said that they would consider backing out of the existing channel if the Pierhead Channel would be available to perform the turning maneuver. Few pilots said they would choose to back with their vessel broadside to a maximum flood current with augmenting wind conditions. The strategy used by the pilots consisted of putting the engine to full astern and trying to gain enough speed to overcome the currents before reaching the end of the terminals. The vessel is kept inside the channel with the use of tugs. One pilot used a tug at the stern to pull the ship out into the Anchorage Channel.

The composite ship track plots of the outbound run conditions backing into the Anchorage Channel and turning are shown in Plates 25-29 for the existing condition, the 250-ft, the 300-ft, the 370-ft, and the 440-ft channels, respectively. It can be seen that the backing operation is not very controllable as evidenced by erratic tracklines which often go out of the channel, even in the existing condition. The ship speeds could not be made high enough to overcome the current forces using reverse RPM. The tugs could not hold the ship against the currents when the speed of the ship increased. Attempting to steer the ship while backing was difficult because as the ship speed increased, the tugs were not as effective. In fact, the erratic behavior of the ship appears to become worse as the channel becomes larger. This could be due to the fact that there is more room so the pilots feel they can depend less on the ship speed and more on the tugs. This is the strategy which seems to work better in the existing channel (Plate 25) than in the proposed conditions.

Outbound ahead. The 950-ft ship was coned outbound starting with the ship heading eastward and going forward without tug assistance. This test was only conducted in the 300-ft channel. The results (shown in Plate 30) are generally good and the ship appears to be in control. The outbound runs tended to stay on the south side of the channel in the terminal reach and the composite tracks take most of the approach channel. A few of the ships waited too late to begin the turn south into the Anchorage Channel or were going too fast and went out of the eastern side of the channel. With the wider channels, and particularly with the taper on the south side of the channel tested with the 440-ft channel, it appears that the strategy to enter the terminal area, turn the ship, dock and discharge the load, reload, and the exit going forward is the preferred method of operation for this channel.

Turning Basin

The turning basin was the same size in all tests; therefore, all runs were combined into plots based on the ship size (Plates 31 and 32). In the turning basin, the 950-ft ship definitely takes more maneuvering room than the 850-ft

ship. However, the turning operation with the 850-ft ship exceeds the turning basin dimensions in many cases. Of the 15 turning basin tests with the 850-ft ship, 11 were run in the existing channel (Plate 33) and four were run with the 300-ft alternative (Plate 34). Three of the 11 runs in the existing channel exceeded the boundary of the turning basin. This, in conjunction with the pilots' statements that these ships presently use this turning basin, indicates that the turning basin is of sufficient size for the 850-ft ship with a 35-ft draft. However, in the 300-ft channel three out of four runs went out of the turning basin. This illustrates that by narrowing the channel the turning maneuver becomes more difficult. The reason for this is the pilots must maintain a higher speed in the narrower channel and must do more slowing down in the turning basin resulting in less control of the ship.

In the existing channel, there is a buoy at the west end of the turning basin to mark the extent of the available area. In the tests with the 950-ft ship, this buoy was replaced with a range marker and moved farther back in the channel well beyond the location of the deepened turning basin. Many of the 950-ft ship turning basin test went outside the western edge of the turning basin. It is believed that not knowing exactly where the end of the turning basin was contributed to the turns extending too far west. Most of the turning operations were conducted on the southern edge of the channel. This was probably due to the pilots allowing for the south wind to push them farther north than it did. The turning basin is too small for the larger ship under test conditions.

Statistical Analysis

During each run, the control parameters of the ship were recorded every five seconds. These parameters included position, speed, revolutions per minute (rpm) of propeller, rudder angle, rate-of-turn, heading, drift angle, and port and starboard clearances. Test result statistics are listed in Appendix C. The clearances were addressed as part of the tracklines plots since they are closely related. The use of tugs was also included in this analysis. The statistical analysis is presented for two reaches: A and B similar to the track plots. The mean of each parameter was plotted versus distance along a track line which follows the center of the channel. The value shown on these plots is obtained by averaging the parameter for each run and that occurred within each 1,000-ft section, approximately one ship length. This value is plotted in the midsection of the 1,000-ft section. This is similar to the clearance plots previously discussed. This section concentrates on comparing the 440-ft channel with the existing condition since it was noticed that the narrower channel conditions followed the trends of the 440-ft channel. The significant results are discussed below.

Rudder angle

The rudder angle is very definitive as to the preferable setting: less rudder is better. The plots of the rudder angle include a plot called rms. This value is defined as

$$rms = \frac{\sqrt{\sum(x^2)}}{n} \quad (1)$$

where

x = number angle

n = number of data points

The rms is used in a similar fashion to the absolute value of the rudder mean in that it results in a positive value that can be compared to zero to determine magnitude. The rms value clearly illustrates the amount of rudder used. The rudder setting does not seem to change significantly from the existing condition to the proposed conditions (Plates 35 and 36).

The rudder plot of the existing condition (Plate 35) shows that normal procedure has the pilots administering port rudder in Reach B. In the 300-ft channel, a starboard rudder setting is required (Plate 37). This is because the channel is moved to the right. Plate 36 shows that no port rudder is necessary in the 440-ft channel. This illustrates the pilots' tendency to stay in the center defined by the two banks. However, in the 300-ft channel they are unsuccessfully (see Plate 13) attempting to stay in the channel.

Speed and rpm

The speed and rpm were plotted on the same graph because they are so closely related. The rpm setting dictates the speed of the ship. It can be seen from this plot of the existing channel (Plate 38) that the standard operating procedure in area A is to set the rpm at 30 to keep the speed at approximately 8 knots. It seems that in the 440-ft proposed channel the pilots try to remain at 30 rpm but are forced by the narrowness of the channel at the need to maintain control to increase the rpm to almost 70 (Plate 39). This results in an increase in speed which is approaching negligible; however, it is highly significant in that the pilot's have decreased their allowable error without collision.

Heading and drift angle

The heading is the direction the ship is going measured in degrees, north being equal to 0 with clockwise rotation. The most significant example of the information obtained from the plot of heading versus distance along track is

shown by comparing Plates 40 and 41. It can be seen that in the existing condition the transition from the heading set by Anchorage Channel has occurred much prior to the location of the intersection of Anchorage and Port Jersey Channels. In the 440-ft proposed channel, as well as the other proposed channel, an abrupt change in course is necessary.

The drift angle is the angle of motion from the heading of a ship. Pilots call this movement "set". It usually is 1-2 deg either port or starboard. Plates 40 and 41 show that this is an accurate statement for the inbound runs. Set typically occurs when a ship is not traveling parallel to the current. It can also be caused by high winds or the ship "sliding" around a turn. In this case, the only conclusion that can be observed from the drift angle is that for all of the runs in which the pilot backed out it is an order of magnitude off from the 1-2 deg previously discussed as the norm. This shows that the pilots had little control when backing out (Plates 42 and 43).

Rate-of-turn and maneuverability factor

The rate-of-turn, given in degrees per minute, is a measure of how fast the ship is rotating about its center of gravity. Considering the huge mass of a ship, the pilots attempt to keep the rate-of-turn to a minimum to avoid momentum getting out of control. The maneuverability factor is the rpm times the rudder angle given as a percent of the total. Since the pilots use the force of the engine passing the rudder to turn the ship, this parameter indicates the percent of available force the pilots are using to make a turn.

It can be seen in Plates 44 and 45 that generally the absolute value of the rate-of-turn increases followed by a lag which then results in the increase in the maneuvering factor. This lag represents the time it takes for the ship to respond to the command of the pilot. However, the lag shown on these figures does not reflect the actual lag because of combining runs to achieve a mean within a 1,000-ft section creates distortion.

From Plates 44 and 45, it can be seen that the maneuvering factor at the intersection between Anchorage and Port Jersey Channels is twice as much in the existing condition as it is in the 440-ft channel. This illustrates only a 3 deg per minute difference in the rate-of-turn.

Tug forces

The tug plots include three parameters as follows: parallel force, perpendicular force, and moment. The perpendicular force is the desired force and it creates a moment which pushes the ship in the direction the pilot wants it to go. The parallel force is generally unwanted by the pilot because it adds to the speed of the ship. They are usually trying to slow down in the area where tug use would be necessary (for example, a turning basin). The additional speed could even cause the tugs to be rendered useless since the tugs are

effective only at speeds less than three knots. It is important to note that little tug force is used in the existing condition. The tugs are used simply to assist in the turning operation (Plate 46). However, in each of the proposed conditions substantial tug force is used throughout the channel (Plate 47). Generally, the narrower the channel the more tug force used.

4 Recommendations

Plate 48 shows a sketch of the recommendations for channel modification based on the simulator tests. In area A, all of the improved channels tested were inadequate. Alternatively, the channel should be at the Anchorage Channel with a width of 1,700 ft. It should flare down to the 370-ft channel meeting at the R14 buoy on the north side and just beyond the MOT eastern end. The channel should then continue at a width of 370 ft until the GMT pier. At this point, the channel should begin the transition to the turning basin leaving more room near this dock. It is recommended that enlarging the turning basin be investigated further, possibly to 1,300 ft. This would go from bank to bank. If this is not possible due to the proximity of the terminals, the turning basin may have to be moved farther to the west. This would undoubtedly cost more than the proposed conditions. These widenings will assist both inbound and outbound ahead transits. Based on this simulation study, the recommended widenings will make the channel adequate for transit by 950-ft vessels. This is assuming the pilots take advantage of the southern cut in area A during inbound transits. Also, the turning basin must be used. Attempting to back out is not recommended.

A question has been raised as to whether the 370-ft channel is sufficient in Reach B. The plot of the speed and rpm shows that in the 370-ft channel the rpm is decreased 1,000 ft sooner than in the 440 ft channel (Plates 49 and 39). This will assist in the turning maneuver. Also, the 370-ft channel shows minimum clearance values of approximately 50 ft except at the east edge of the turning basin (Plate 17). It is felt that with the additional width at the east edge of MOT and approaching the turning basin this channel will be adequate. This channel is also more economical than the 440-ft channel which shows clearance values twice that required, (Plate 22). It can be seen from Plate 50 that the additional 70 ft on the port side was not used.

These recommendations will increase the dredging costs and the amount of material required to be disposed. It should be remembered that the conditions tested were reasonably extreme. It is believed that the simulation model reproduced the difficulty of handling the vessels in the extreme currents. The currents are not unreasonable; however, they only occur a few days a month during certain periods of the tide cycle. When this is combined with the existence of the 25-knot wind, the probability of occurrence during a transit of

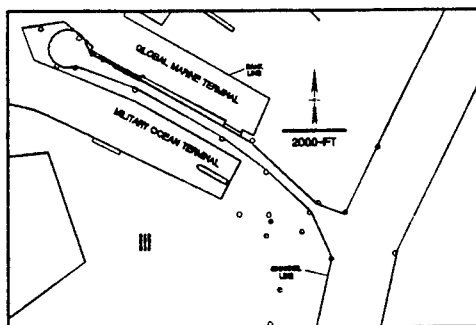
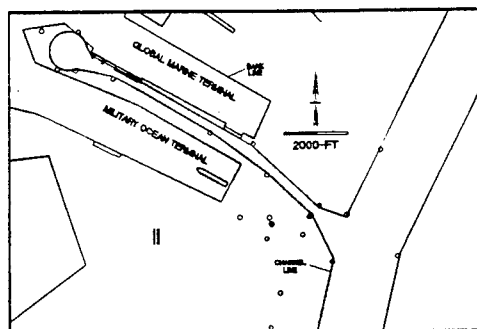
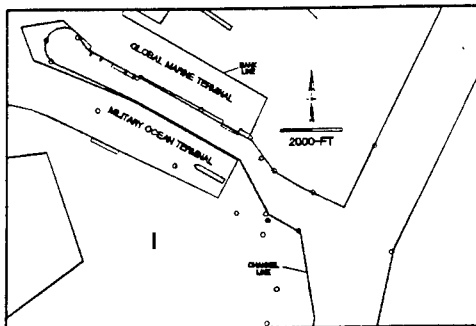
the 950-ft ship is reduced even further. In addition, the pilots are inexperienced in bringing in the 950-ft ship loaded to a 38-ft draft across the currents at such a severe angle. As was noted in the 300-ft channel tests, there was a need to learn the proper strategy for performing these transits. Finally, it should be noted that the tests performed for this study were limited to flood conditions only, due to time and cost constraints. The recommended channel modifications should allow for the setting of the currents to the south during ebb conditions; however, there are no measurements to confirm this engineering judgement.

Two recommendations can be made if the modifications shown in Plate 48 cannot be implemented. The first would involve limiting the operations during spring tide periods when the wind is above a specified level. Likewise, when the wind is high, limit the entrance of 950-ft ships to periods in the tidal cycle when the currents are less than peak flow. When the wind is high, operations in the turning basin will probably require additional tug assistance. There would be some loss to the economic benefits; however, this can be taken into account. The tests reported herein can provide only limited guidance in establishing the levels of wind and current combinations that could be tolerated. It is recommended that additional tests be conducted with the simulator to determine what these limits should be.

In addition to the above, pilot training on a simulator would be beneficial and might allow the development of the appropriate strategy necessary to allow full use of the 370-ft or 440-ft design channel, depending on the level of skill improvement obtained. Since these tests were limited to flood conditions only, such training would also allow the development of the appropriate strategy and skills for handling a ship during maximum ebb flows.

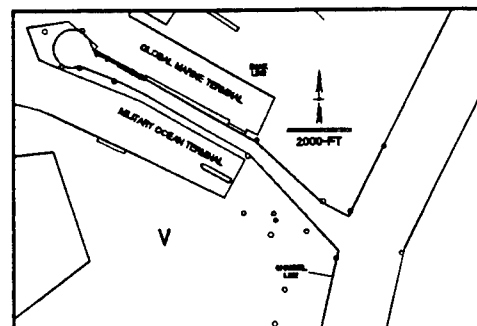
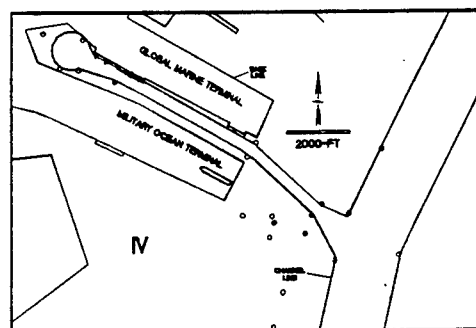
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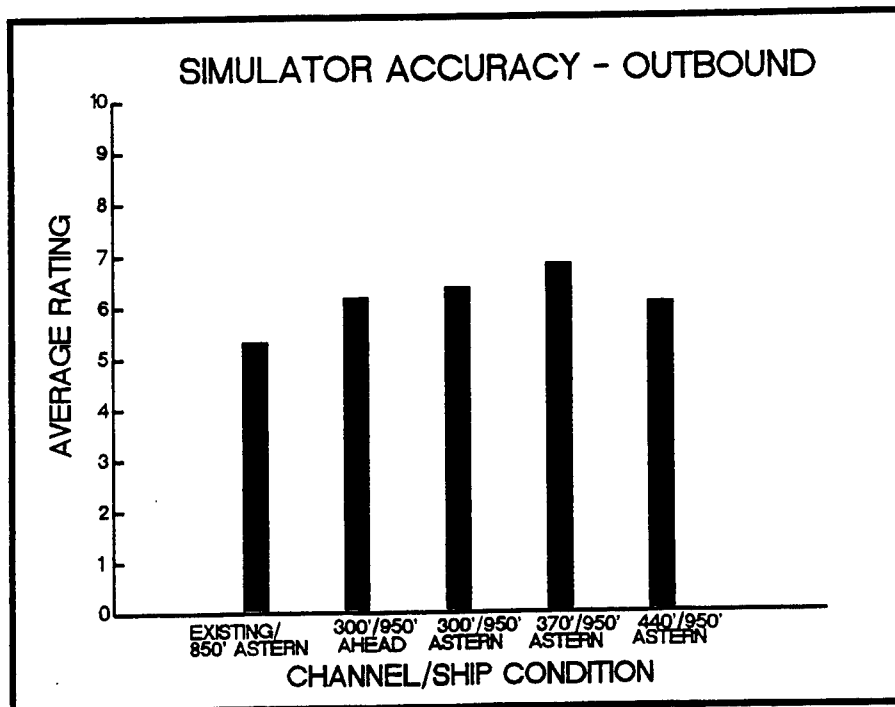
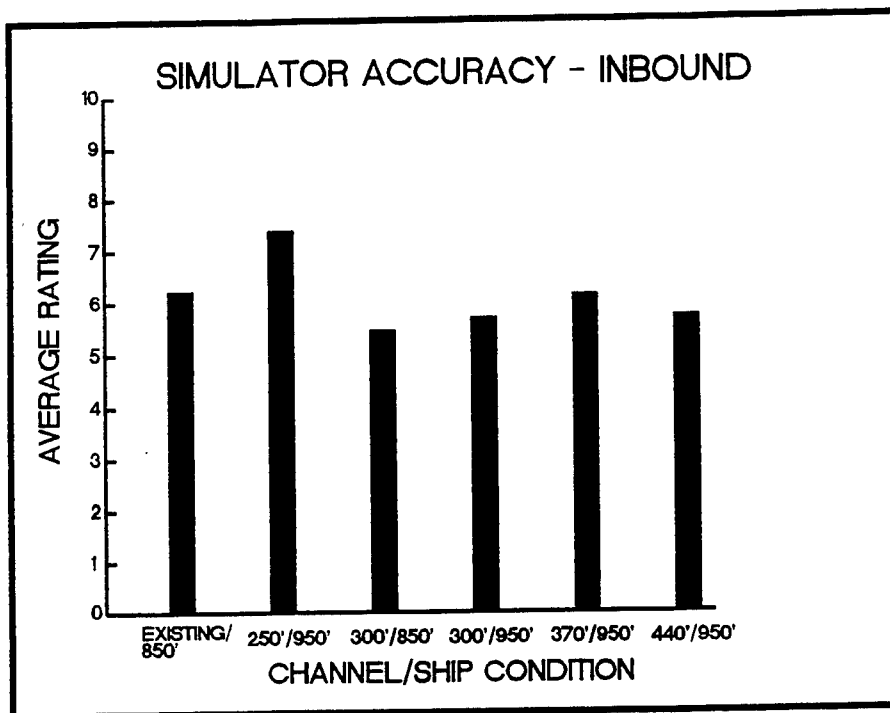
- I EXISTING CONDITION
- II 250-FT CHANNEL WIDTH
- III 300-FT CHANNEL WIDTH
- IV 370-FT CHANNEL WIDTH
- V 440-FT CHANNEL WIDTH



SIMULATOR CHANNEL PLANS

PORT JERSEY

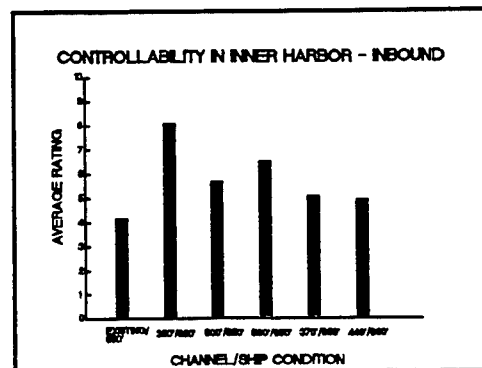
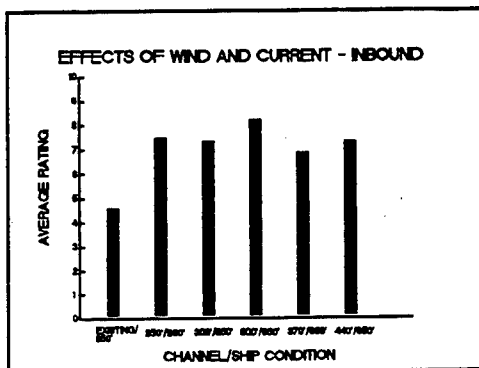
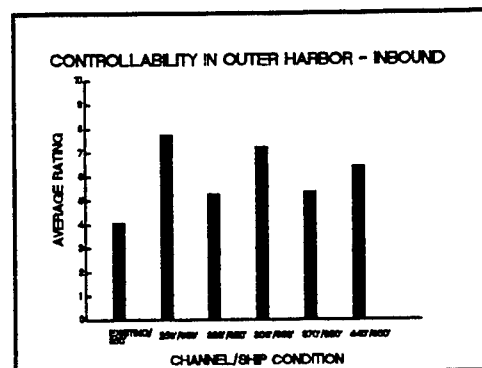
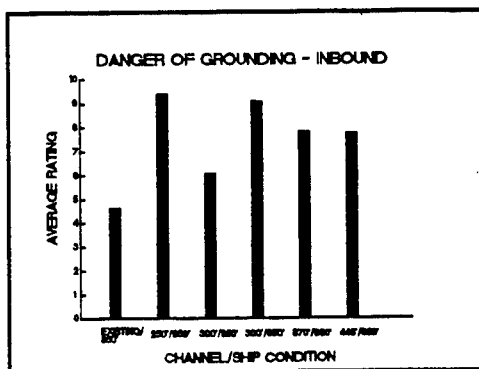
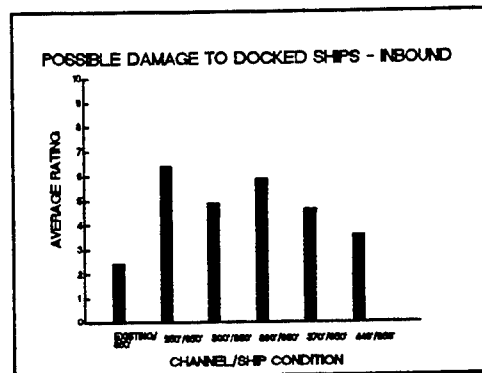
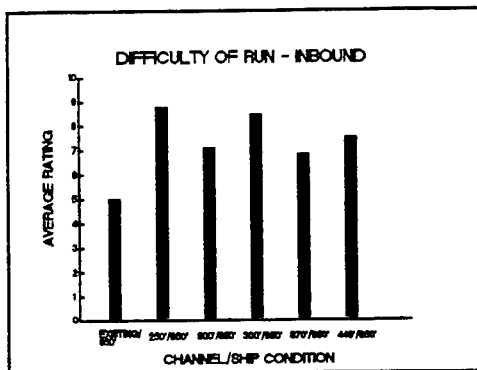
PILOT EVALUATION SIMULATOR ACCURACY



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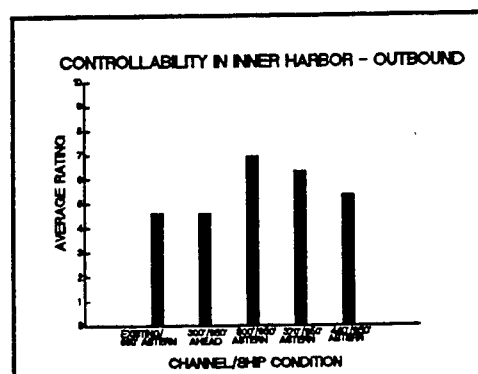
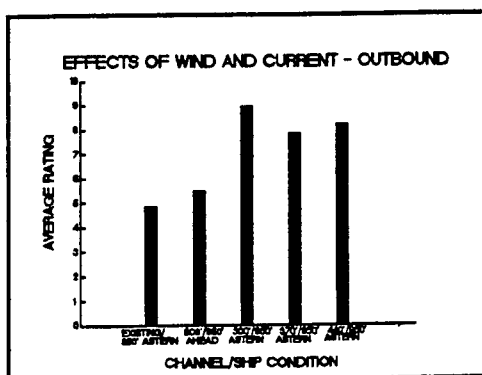
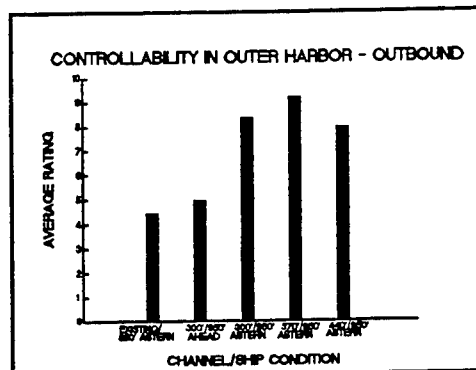
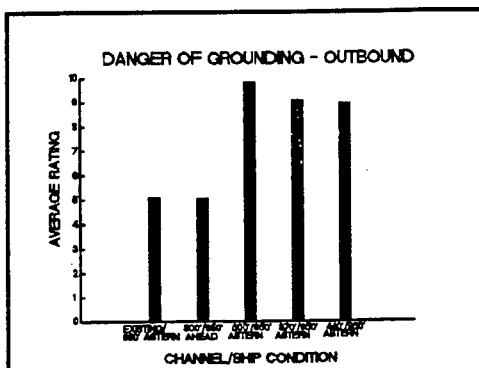
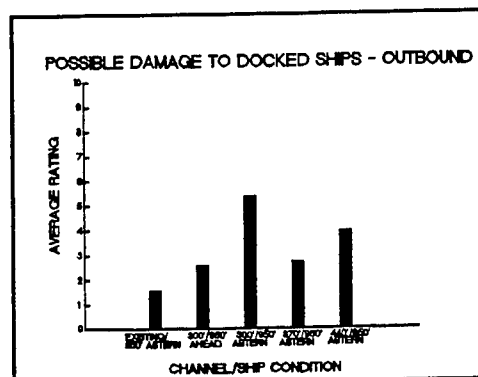
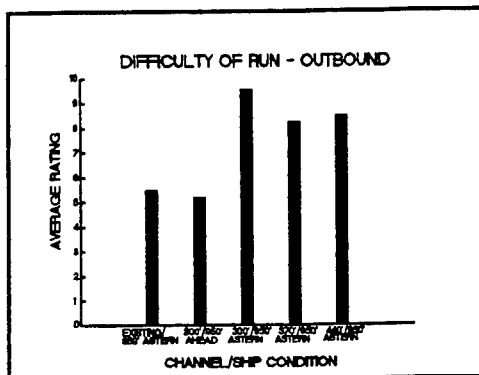
PILOT EVALUATION

CHANNEL PLANS, INBOUND RUNS



PORT JERSEY

PILOT EVALUATION CHANNEL PLANS, OUTBOUND RUNS



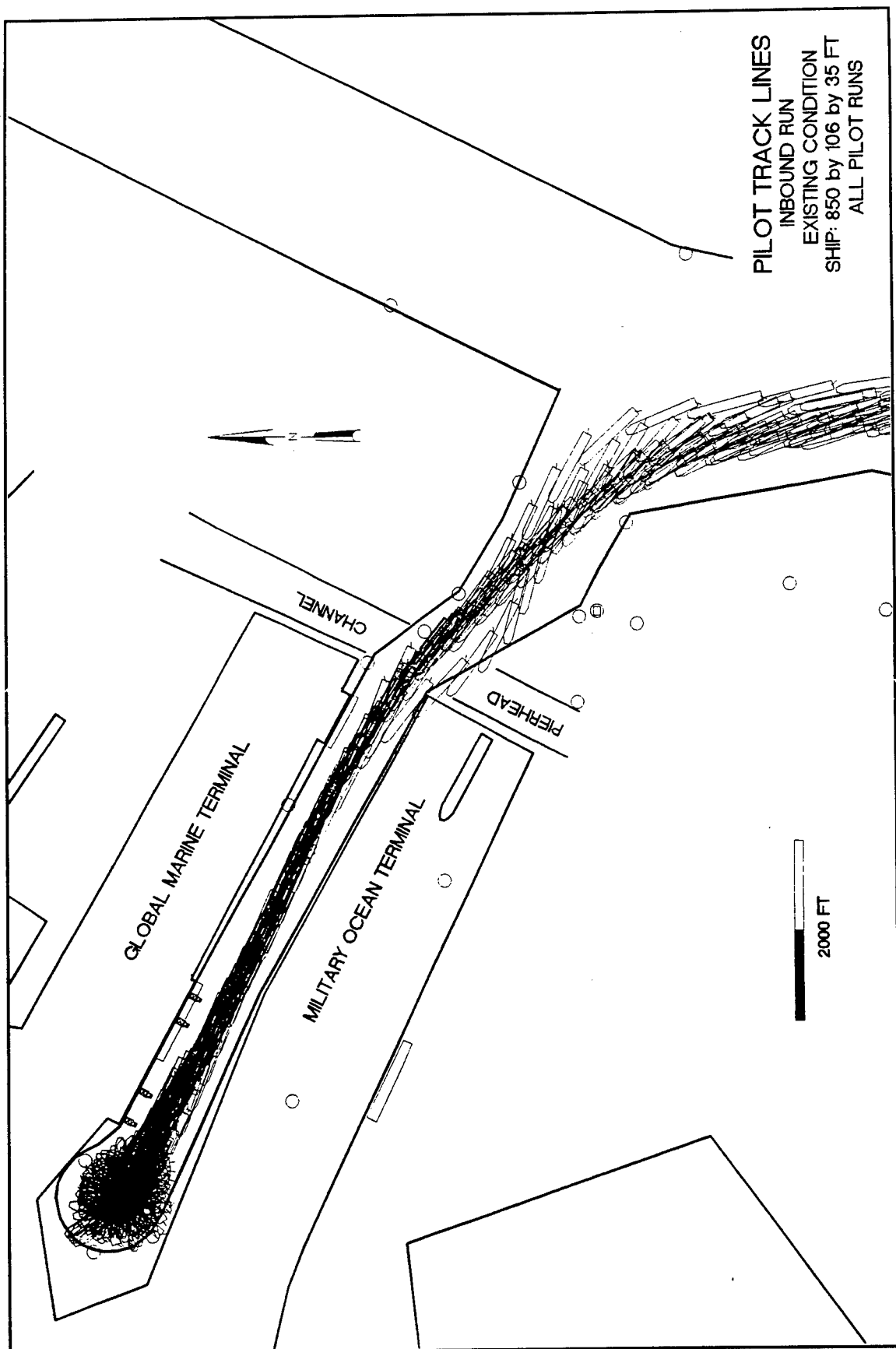


Plate 5

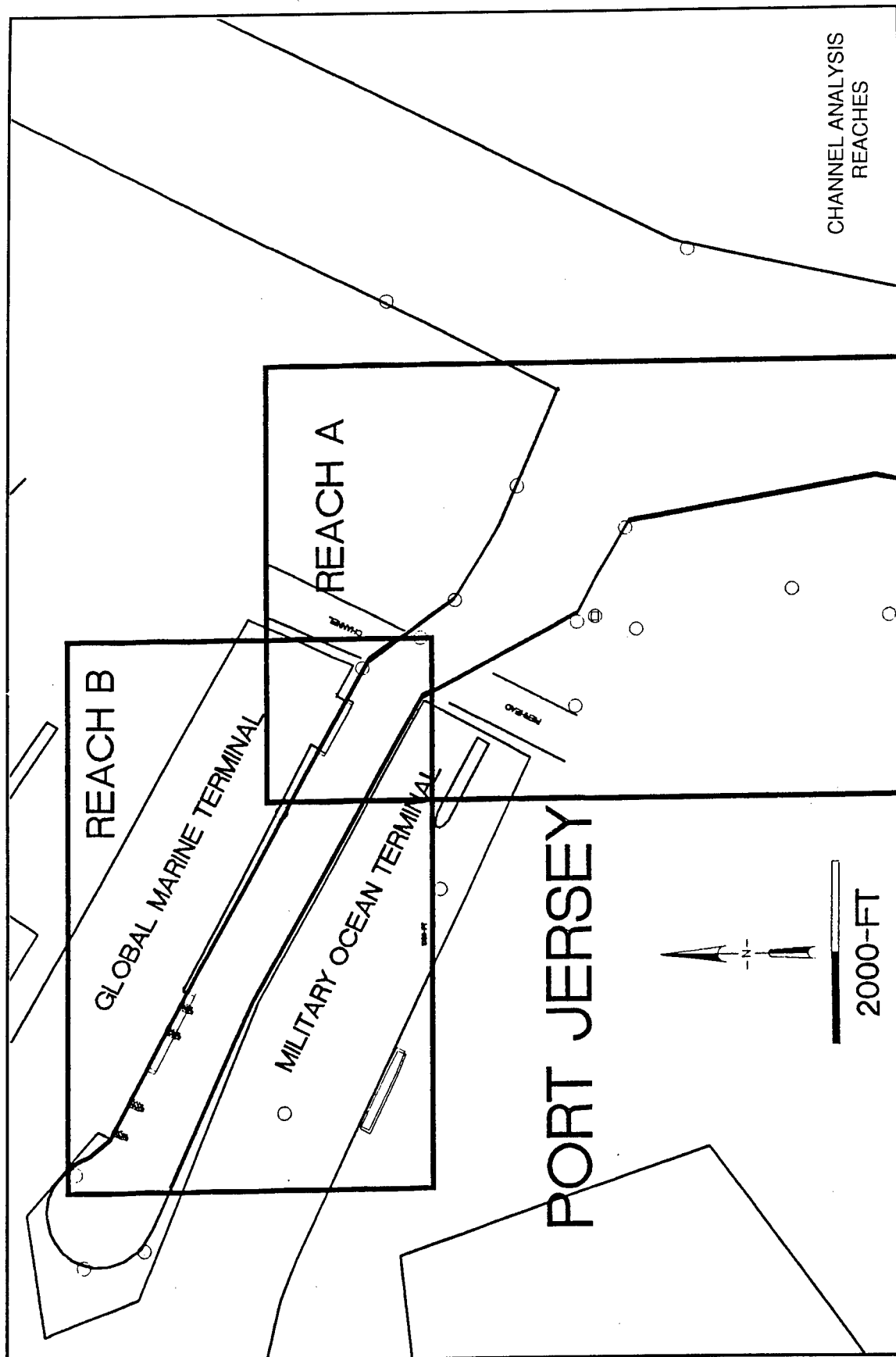
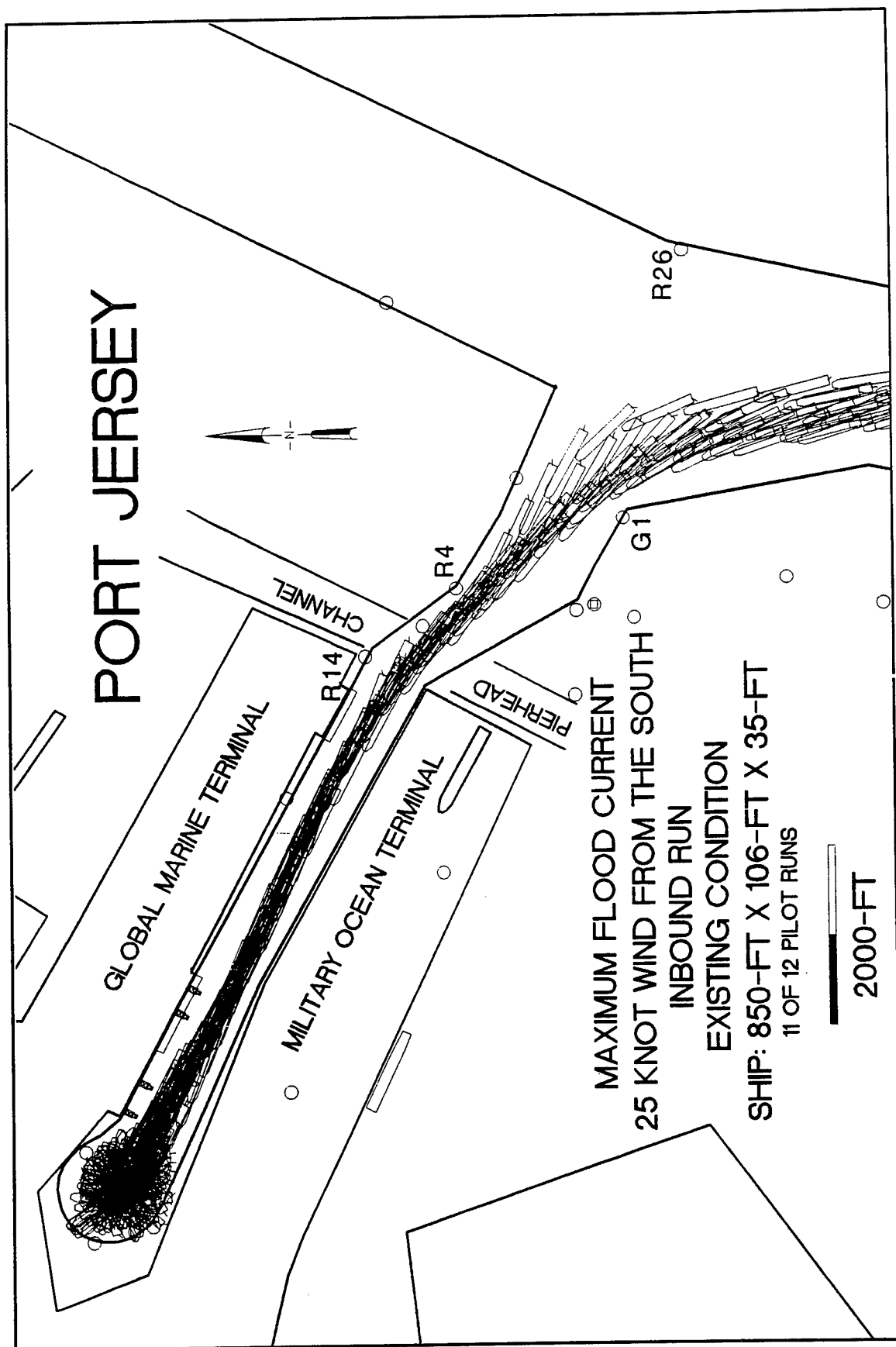


Plate 6



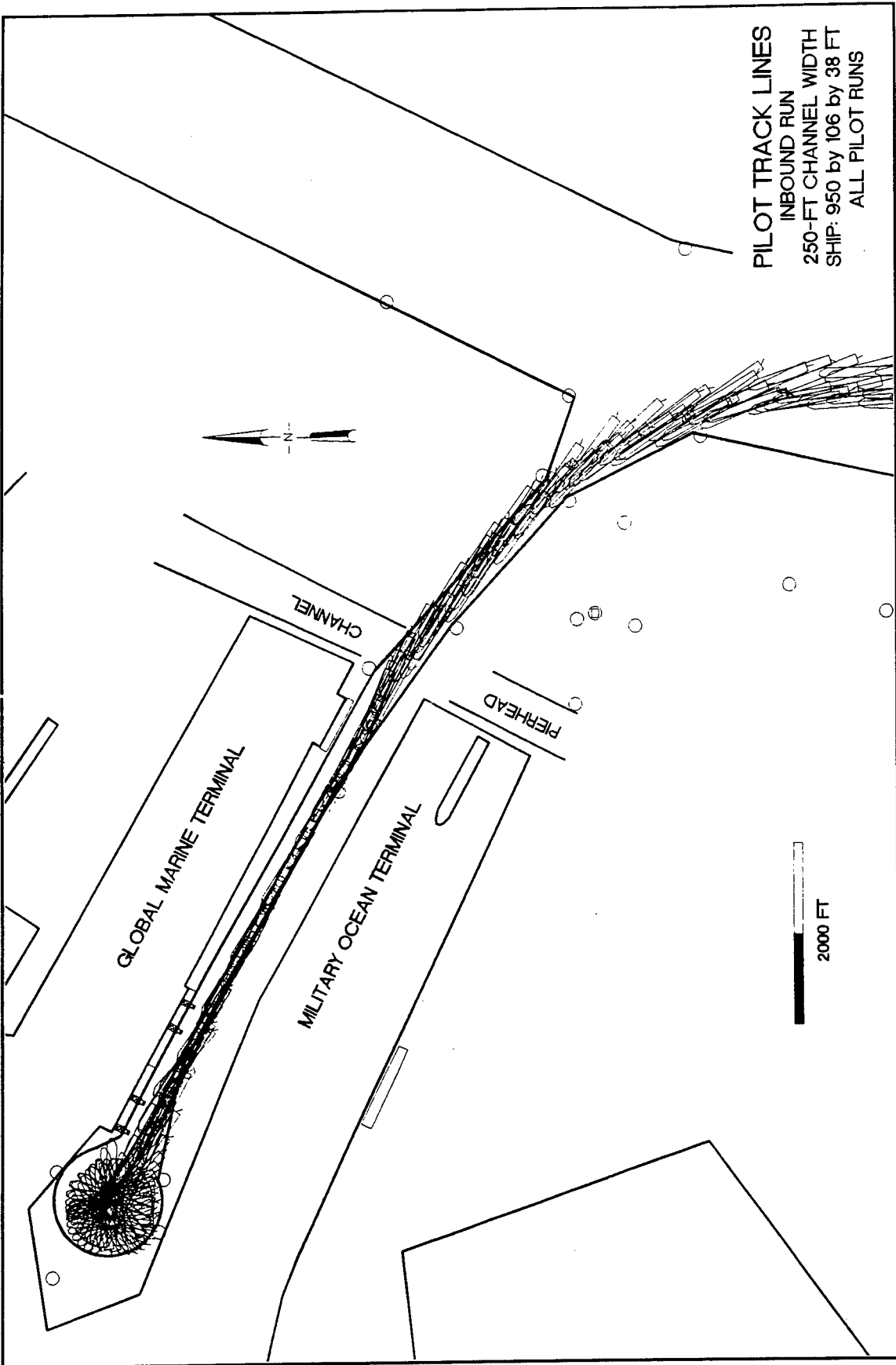
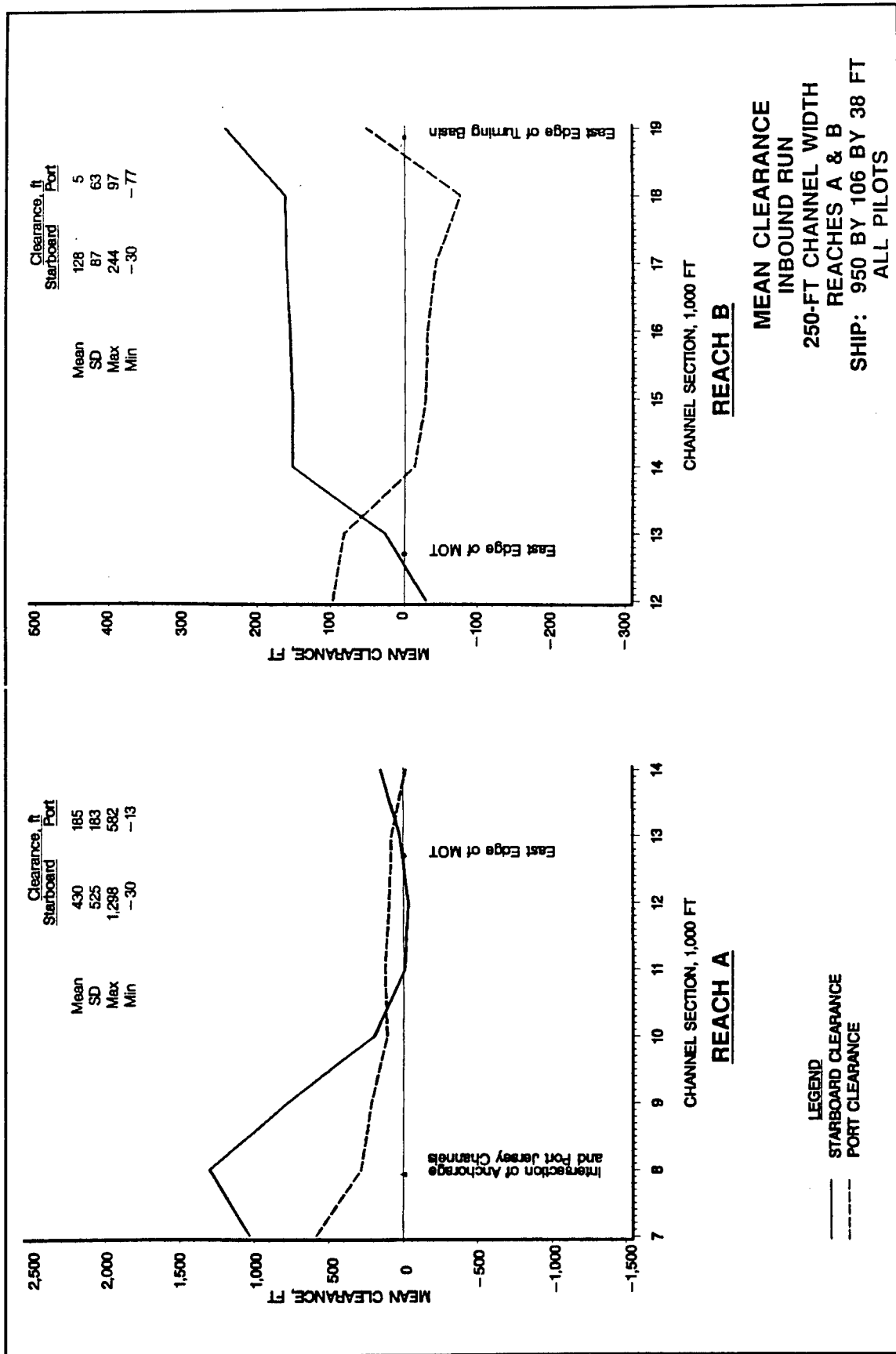


Plate 8



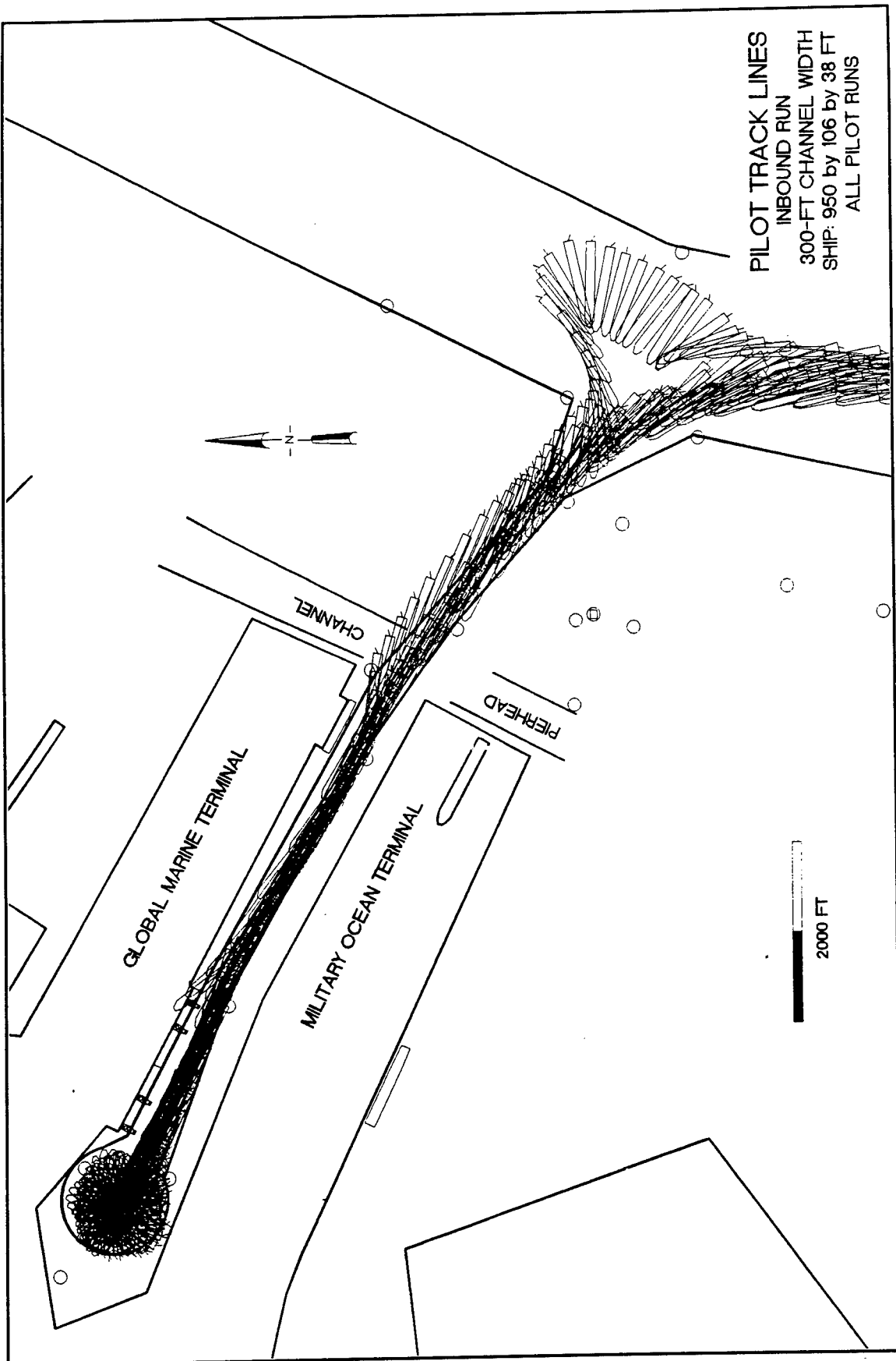
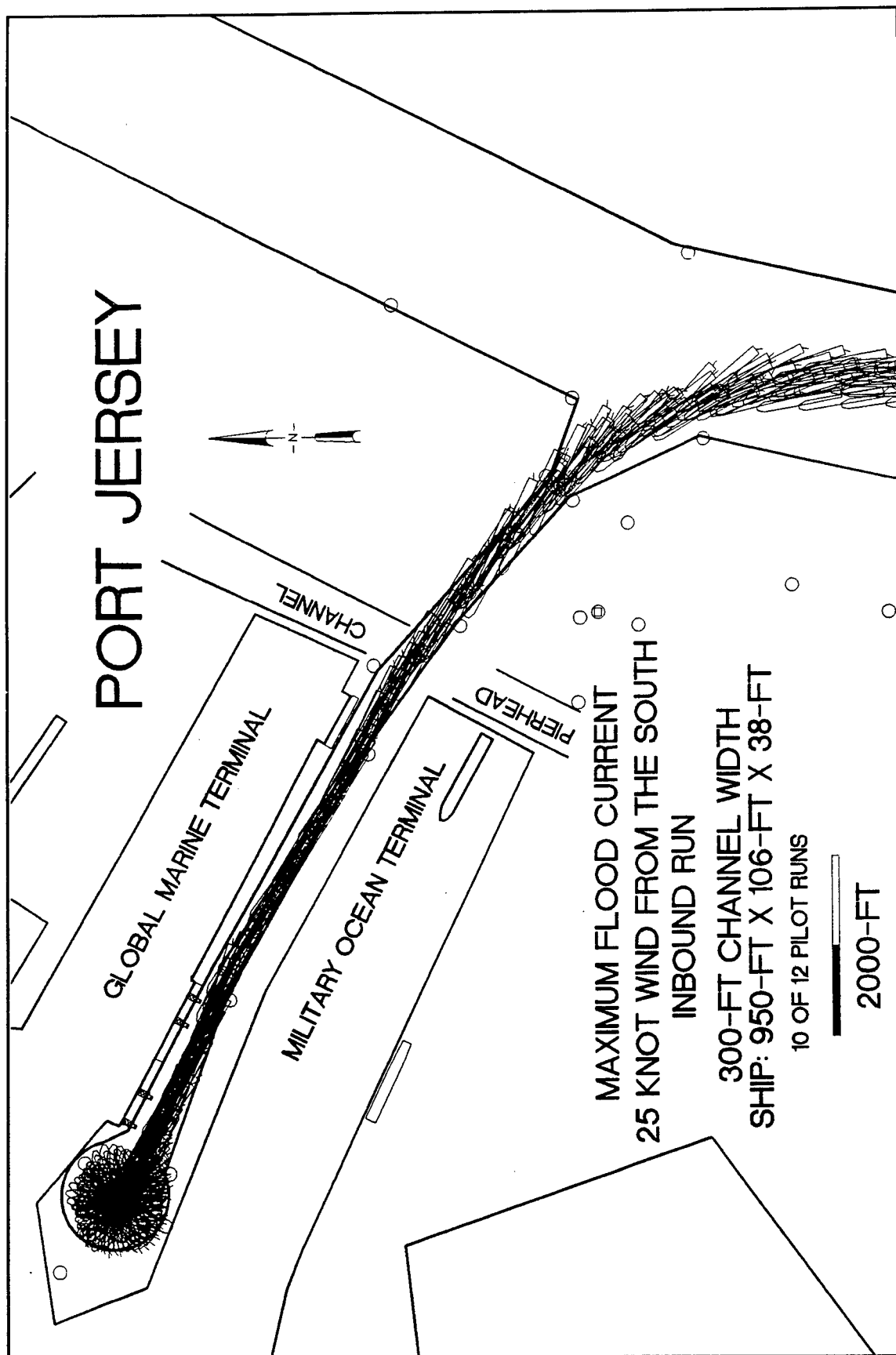
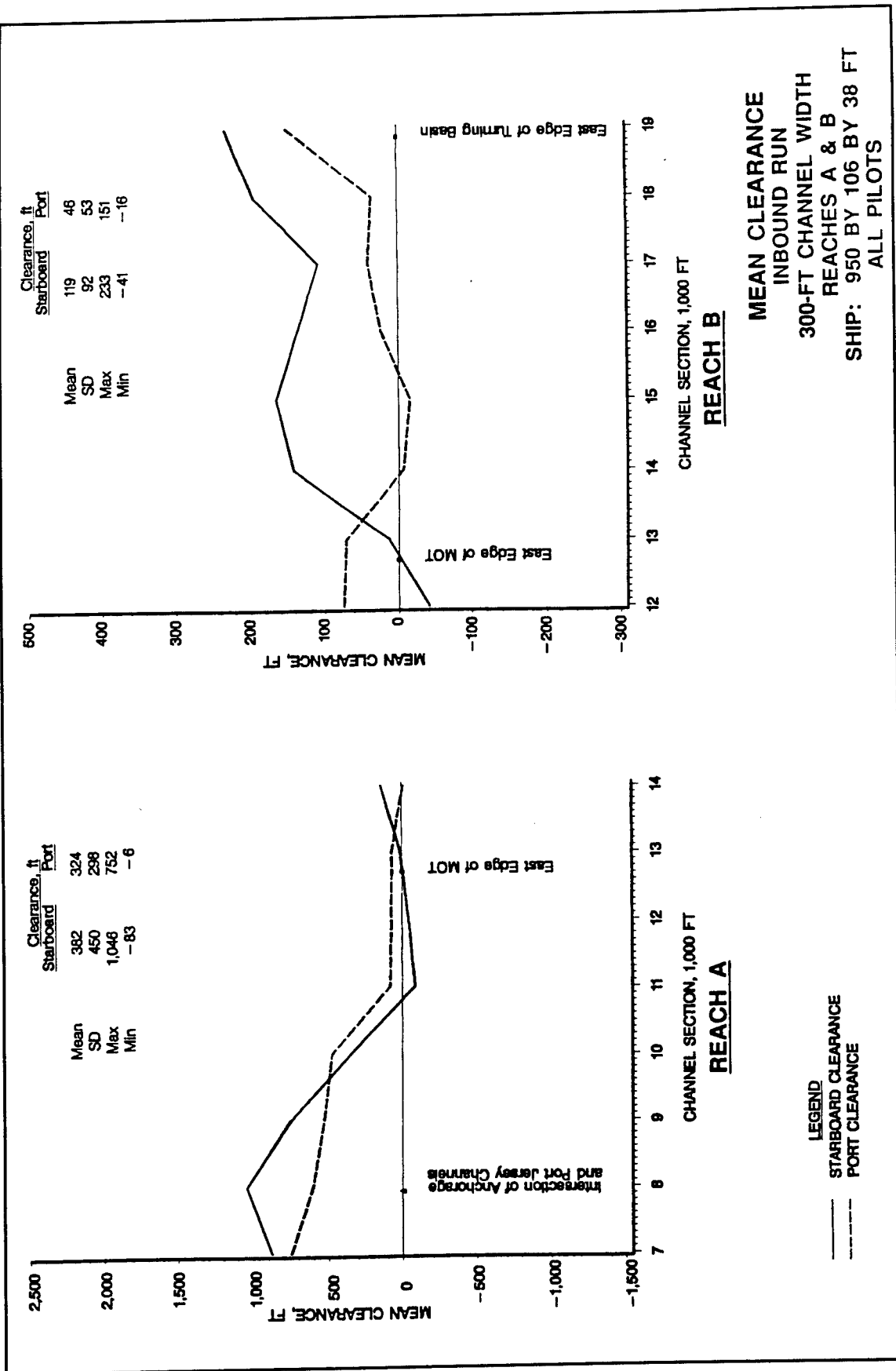


Plate 10





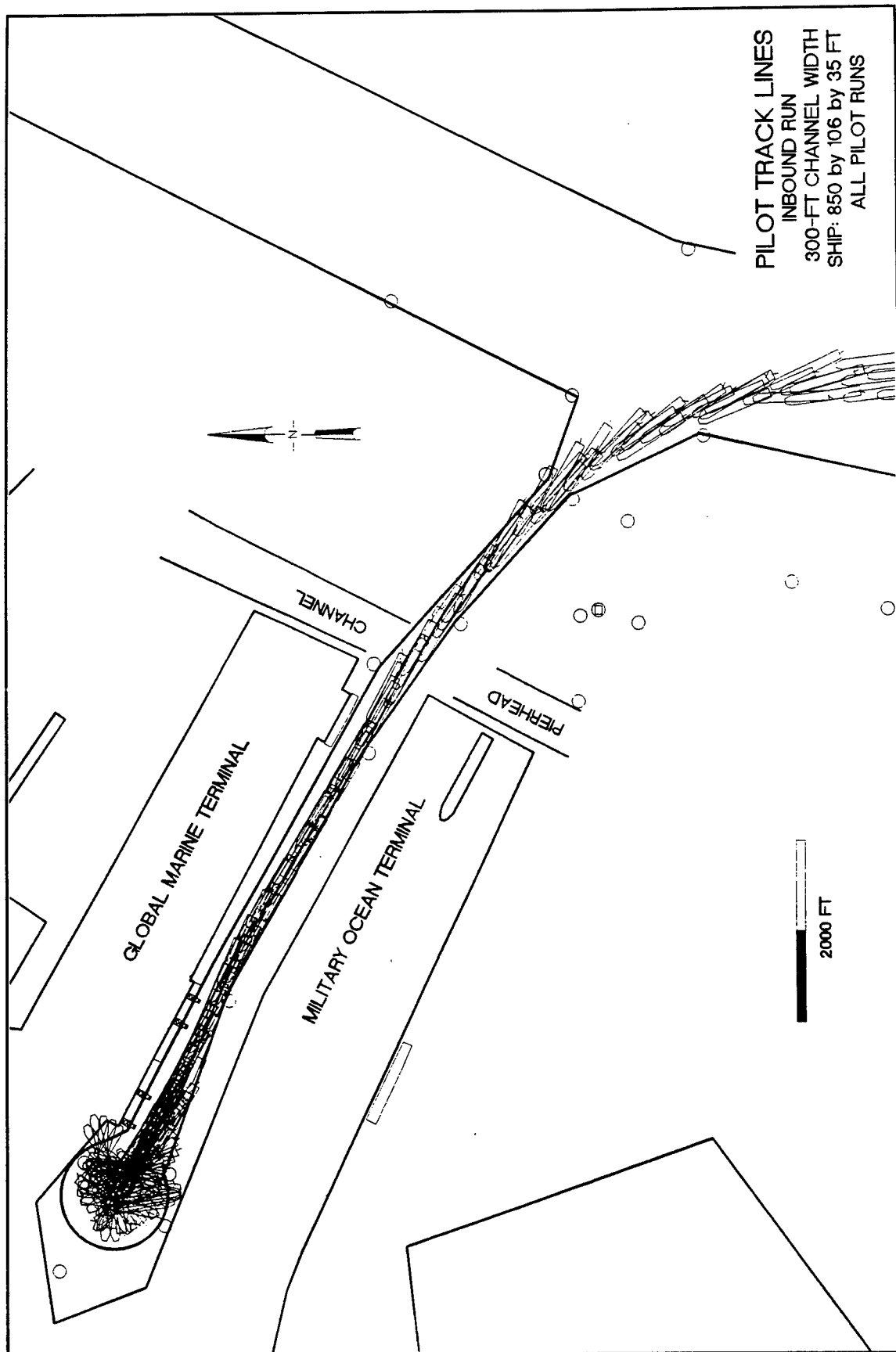
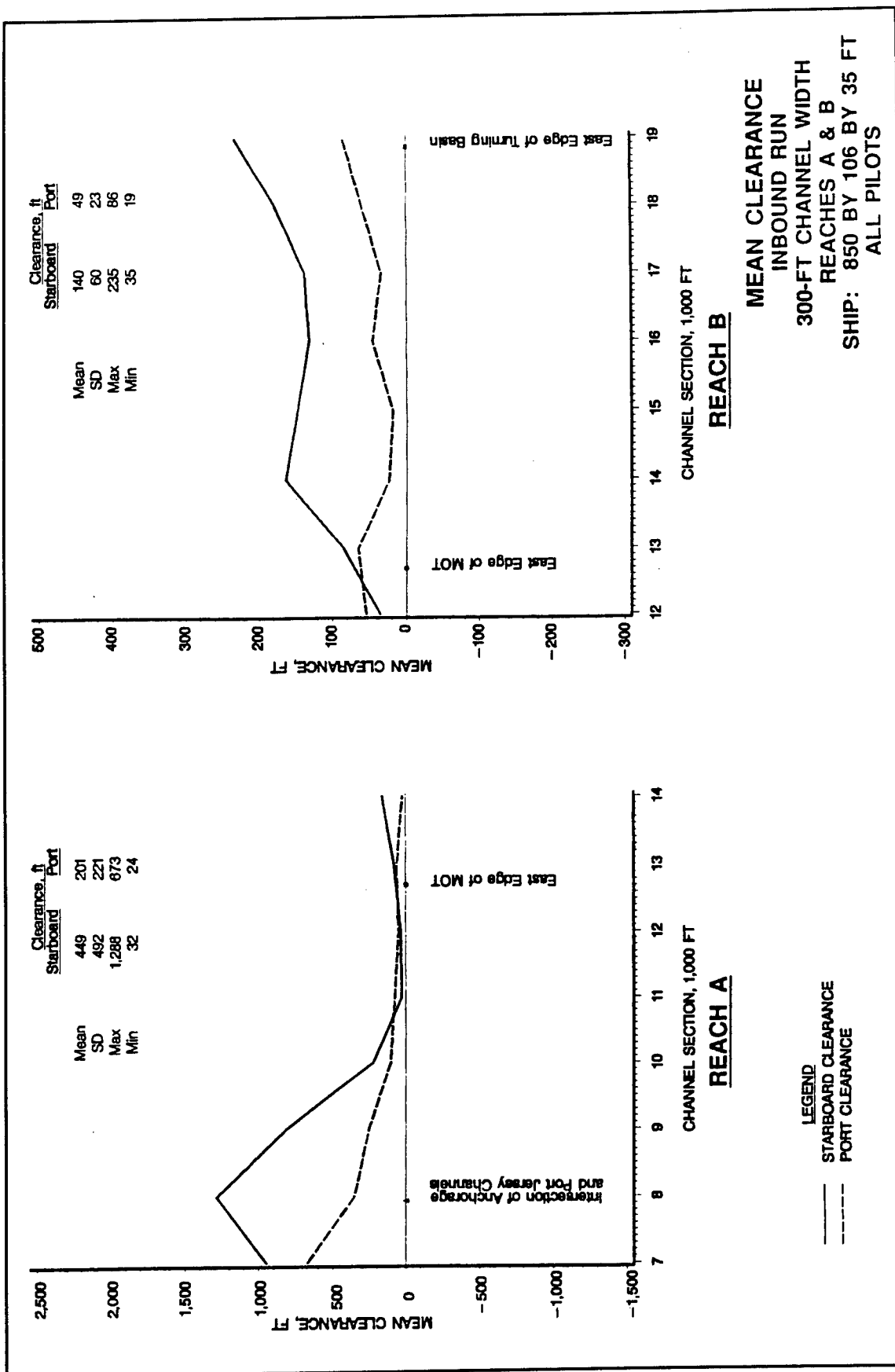
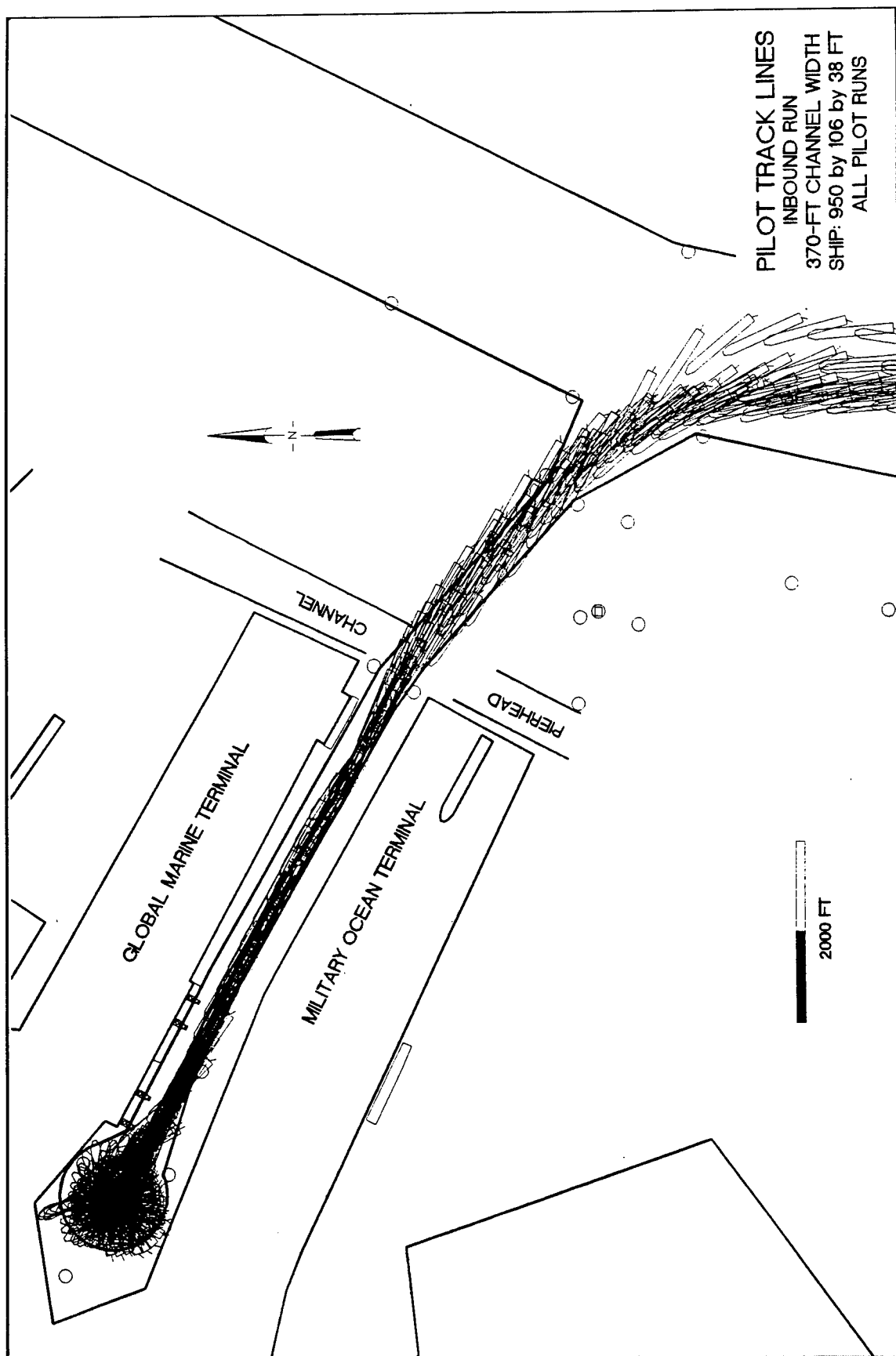
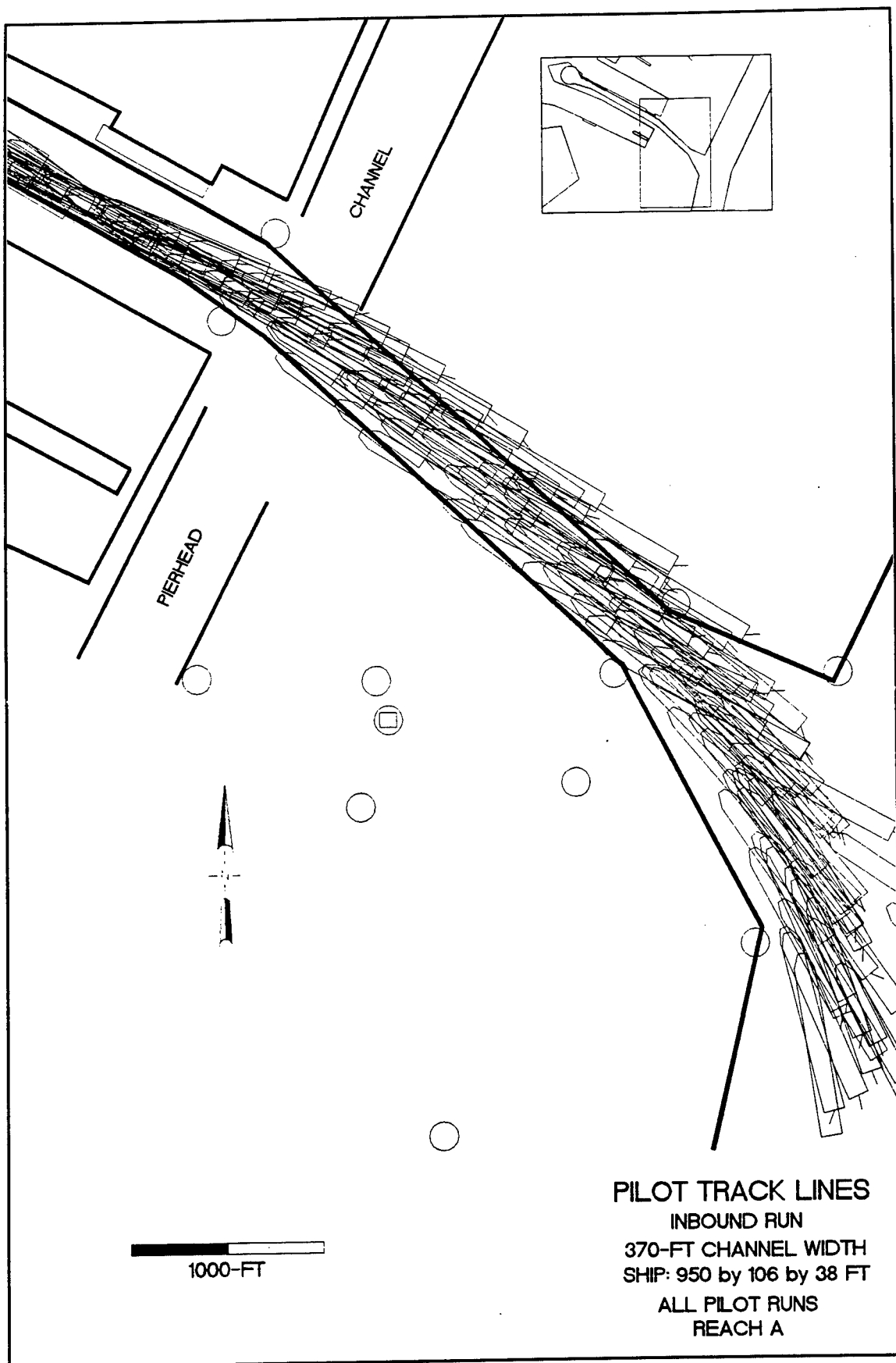
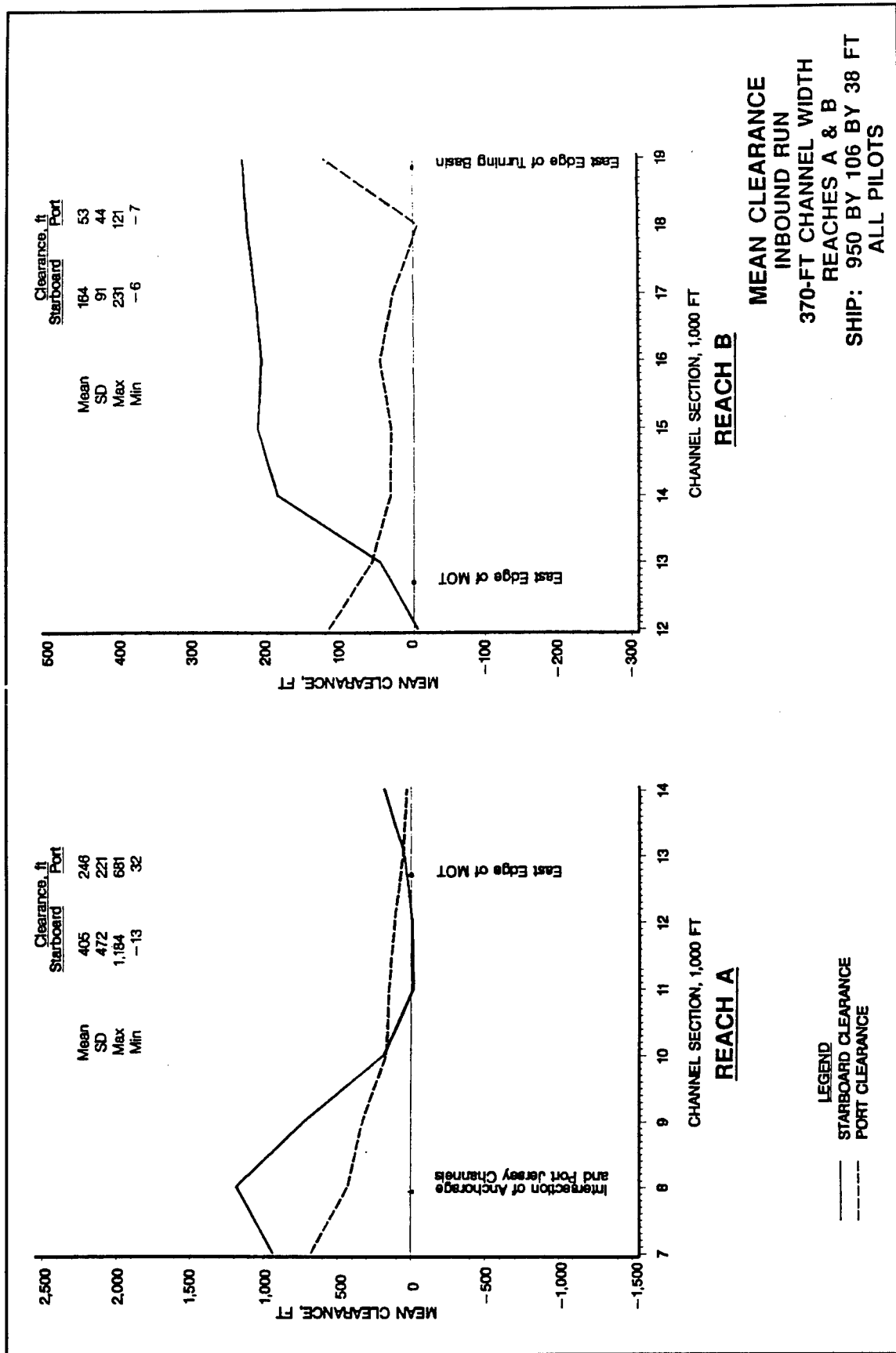


Plate 13









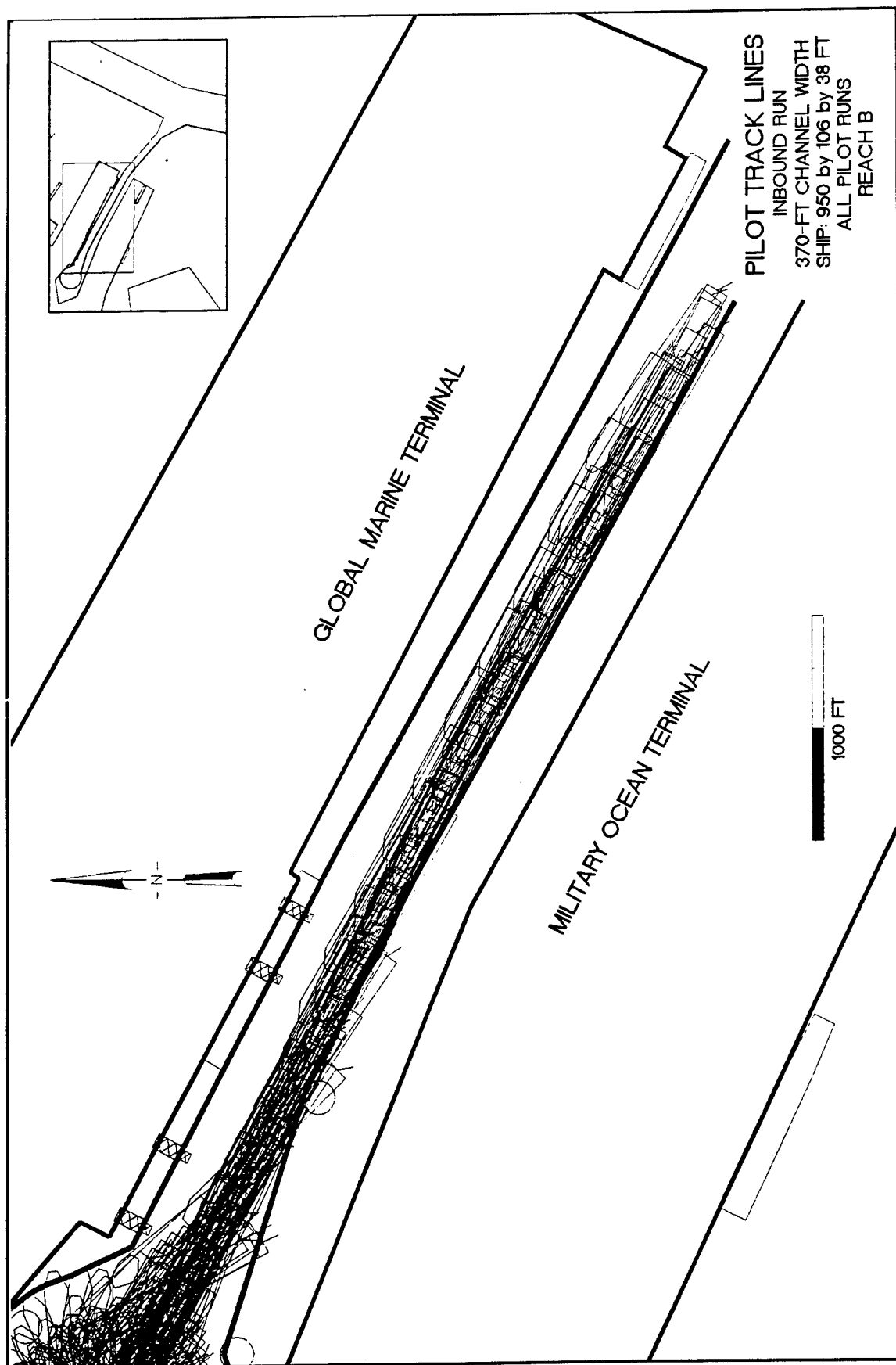


Plate 18

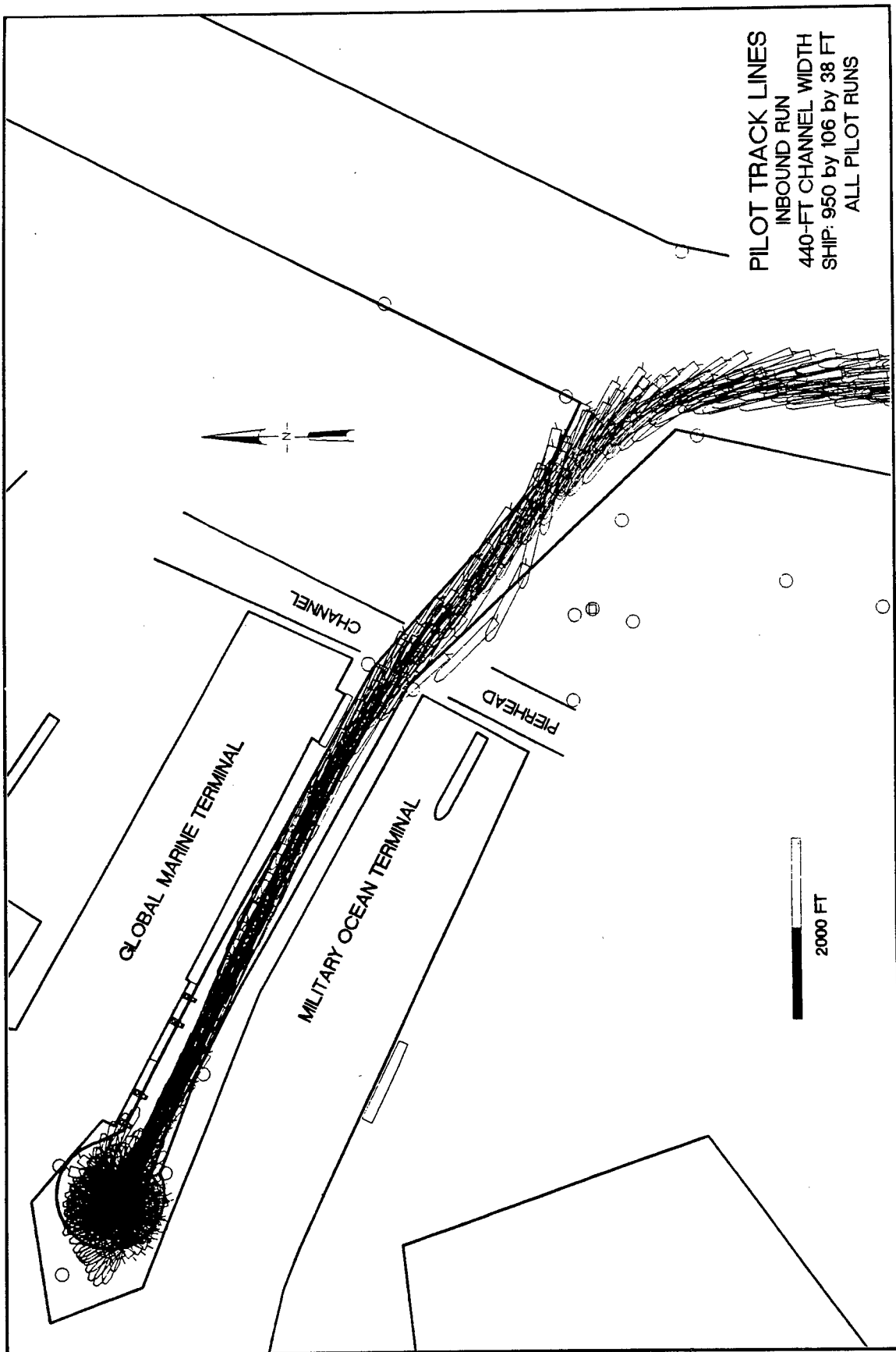
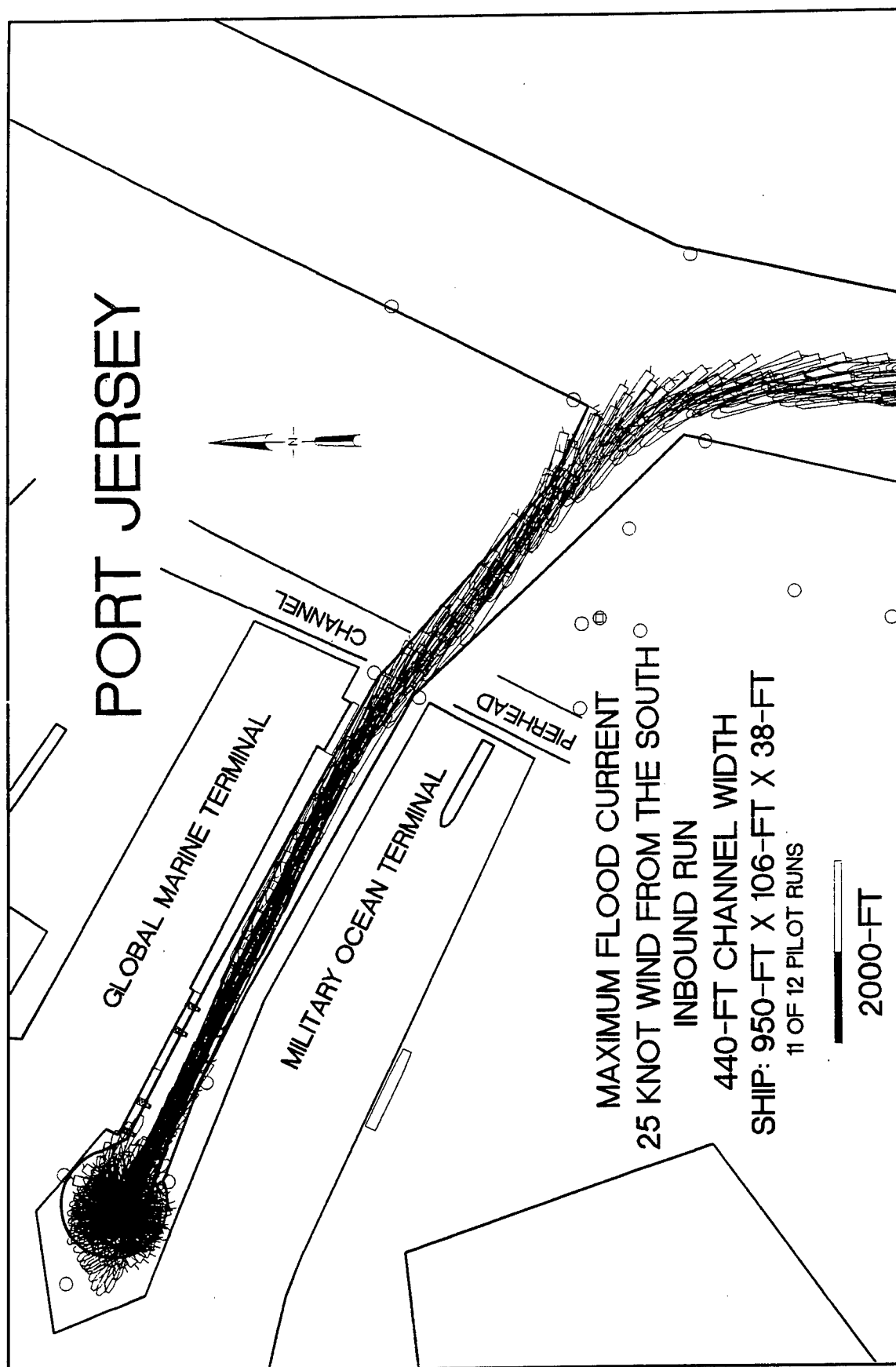
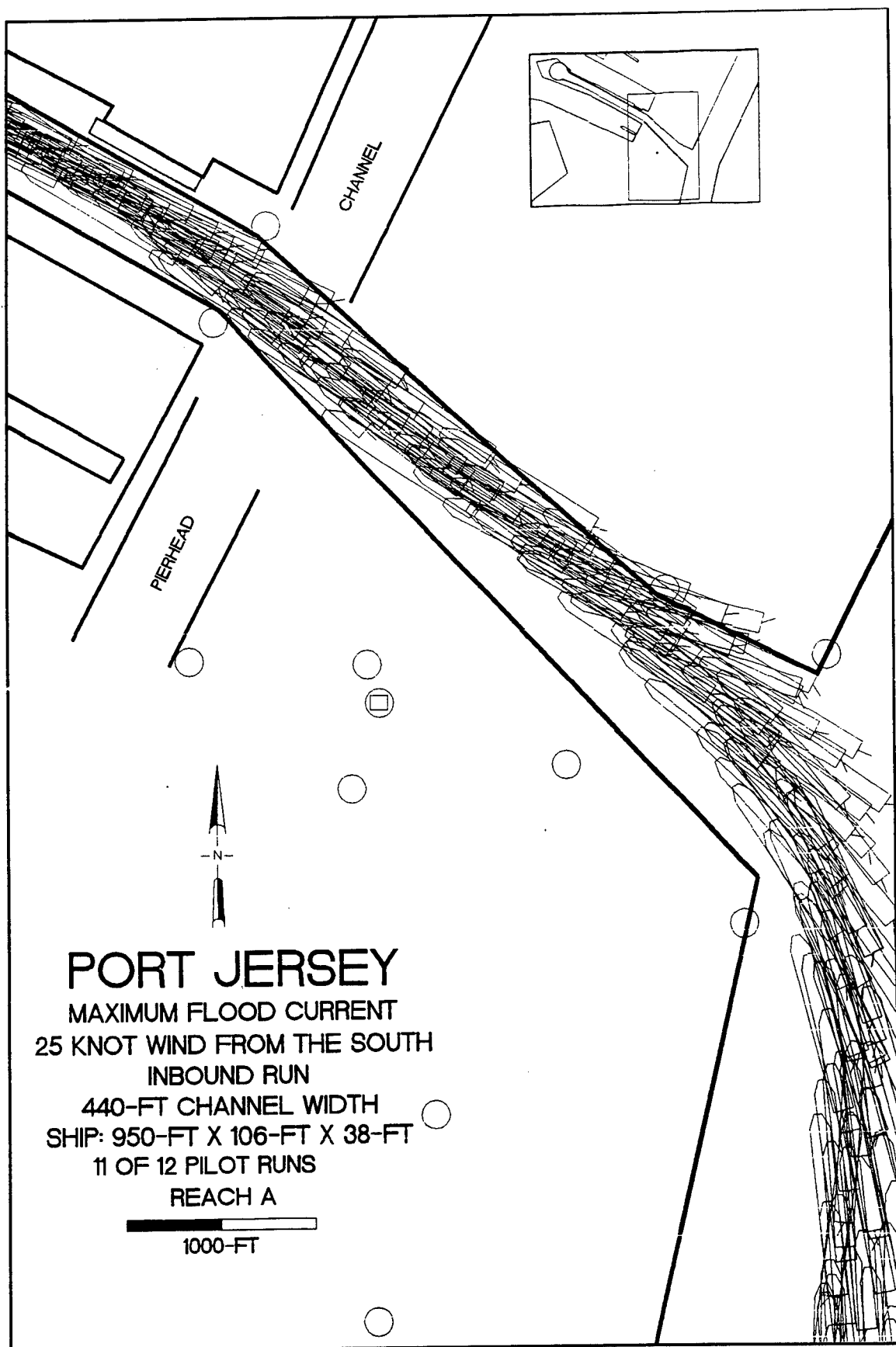
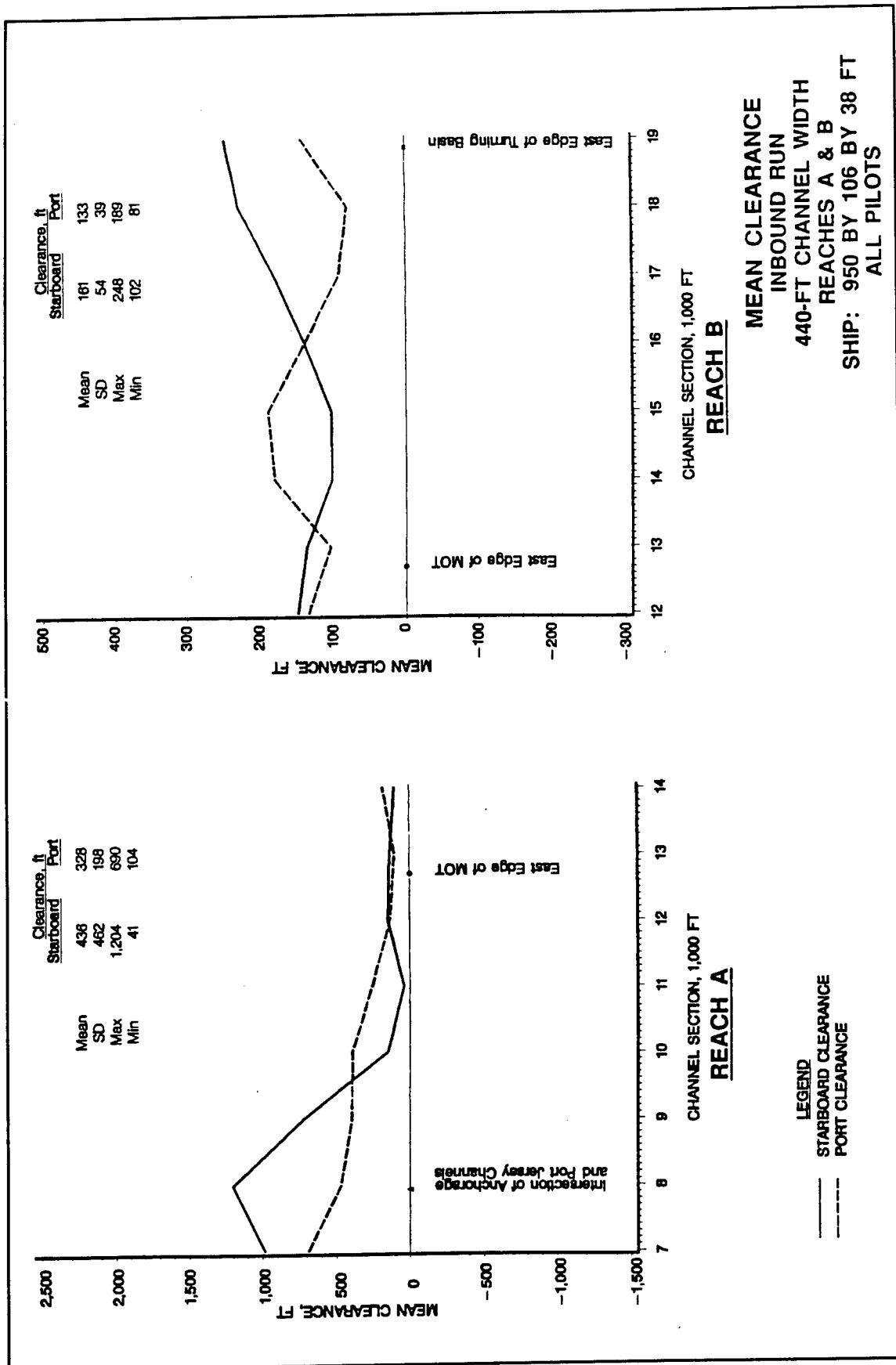


Plate 19

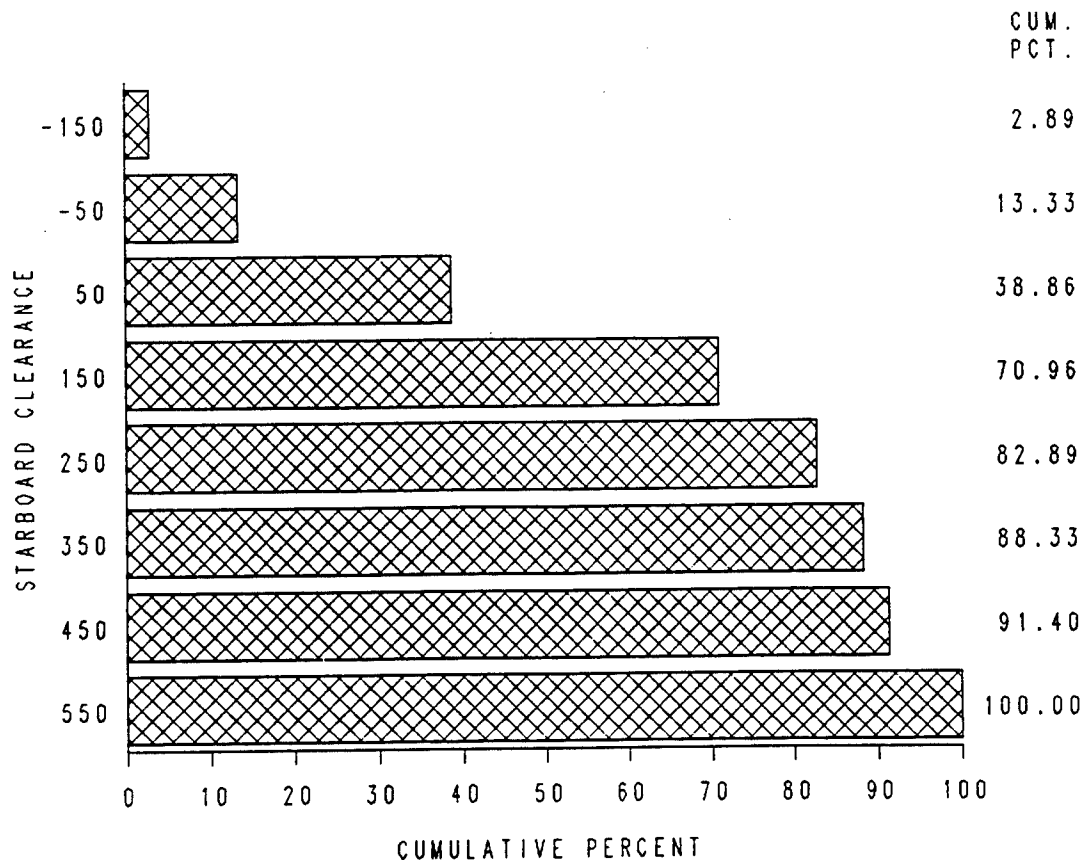






PORT JERSEY

25 Knot Wind from the South
 Maximum Flood Current
 All Pilots
 Inbound Run
 440-ft Channel Width
 Ship: 950-ft X 106-ft X 38-ft
 Reach A
 Excluding Run C14P2



CUMULATIVE PERCENTAGES OF THE MINIMUM
 STARBOARD CLEARANCES
 AREA A

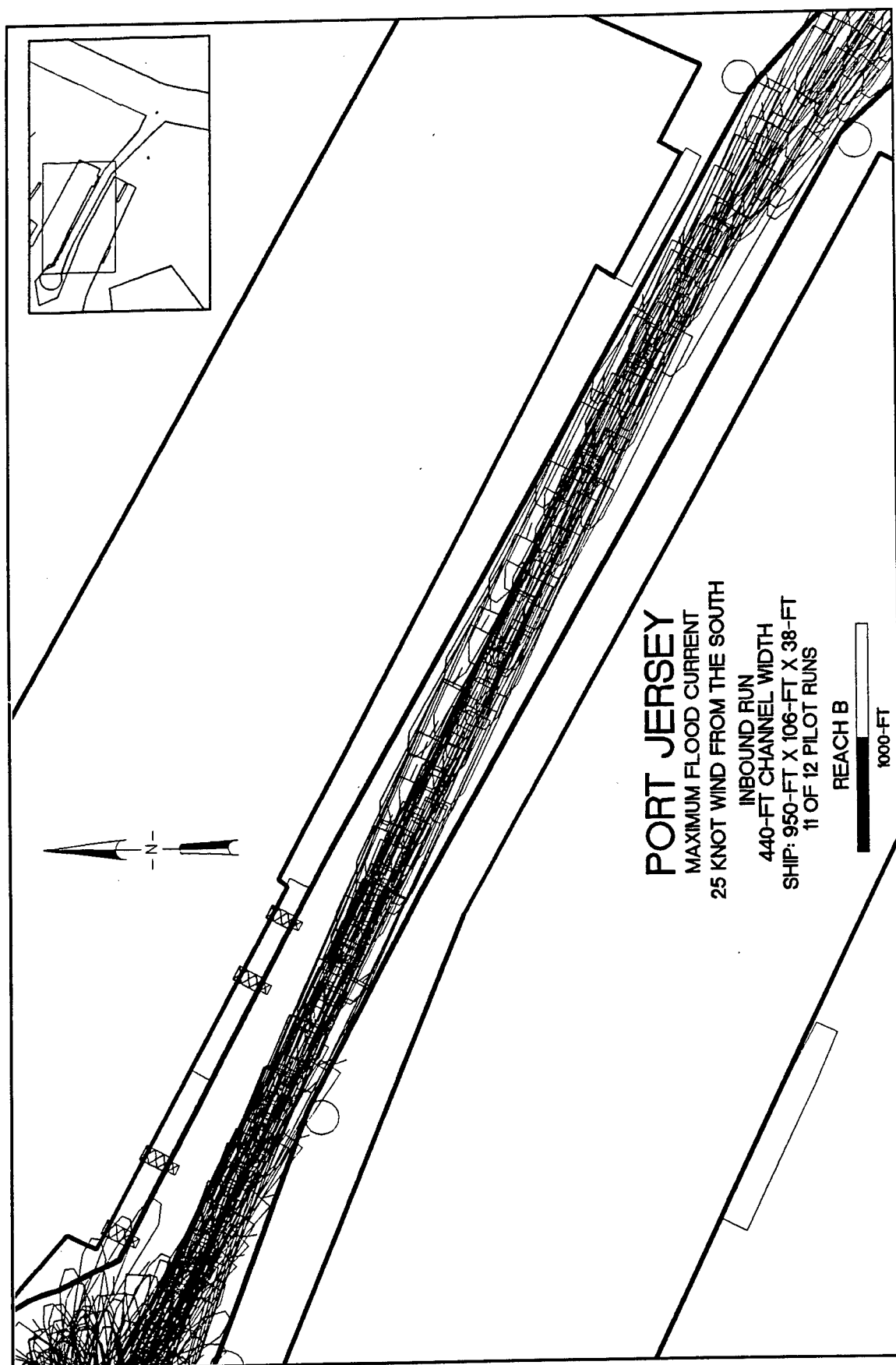
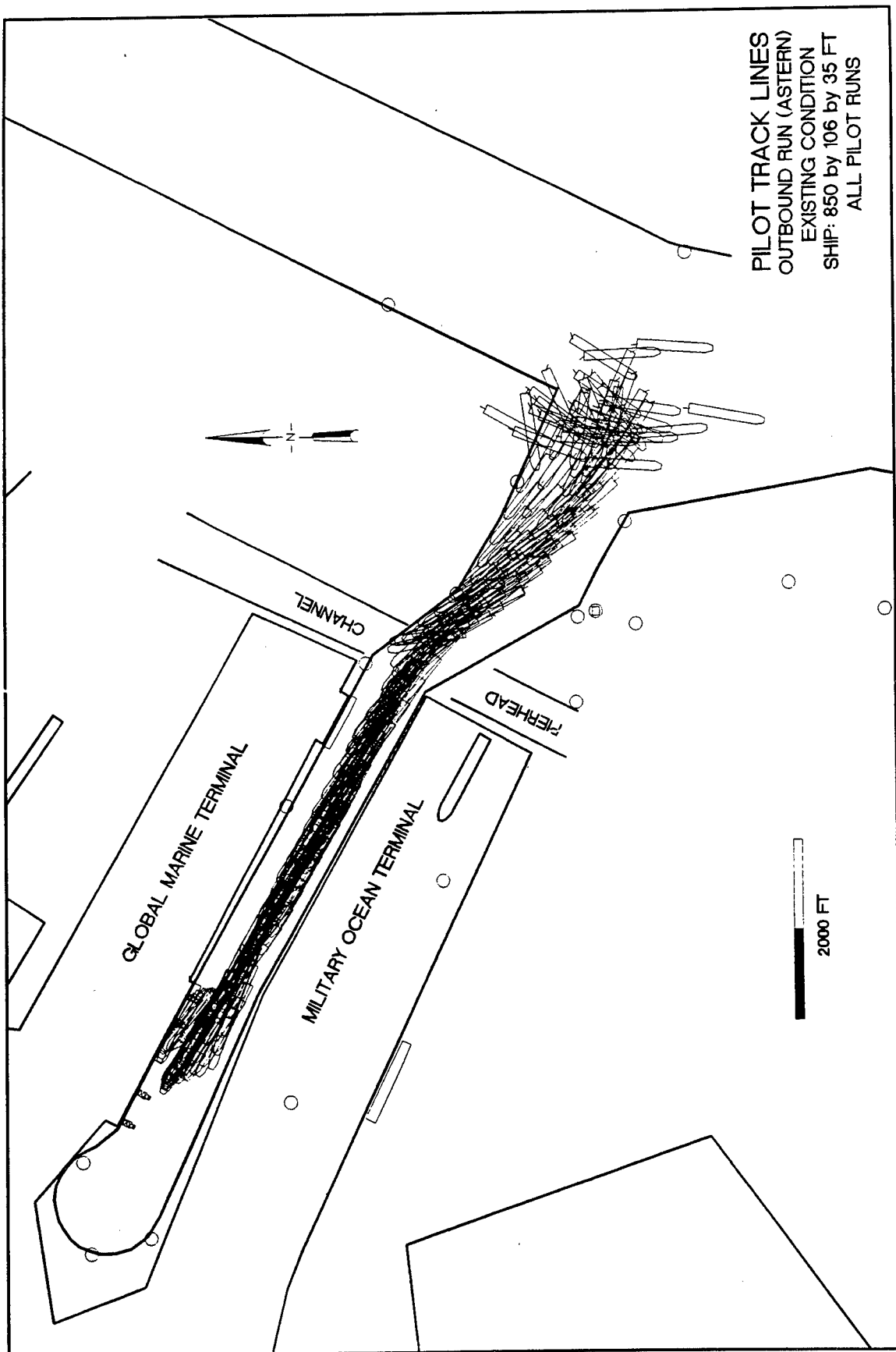
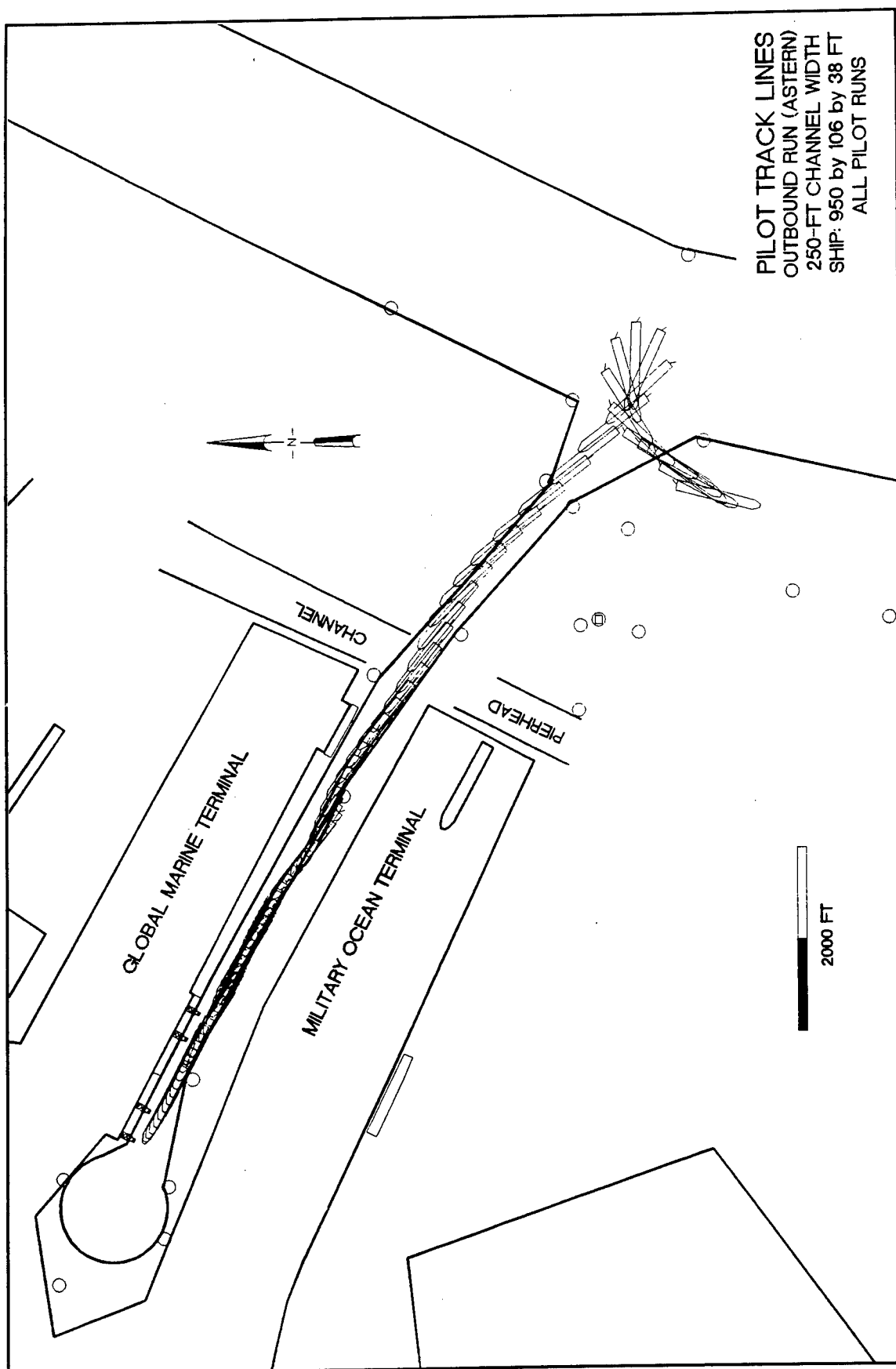
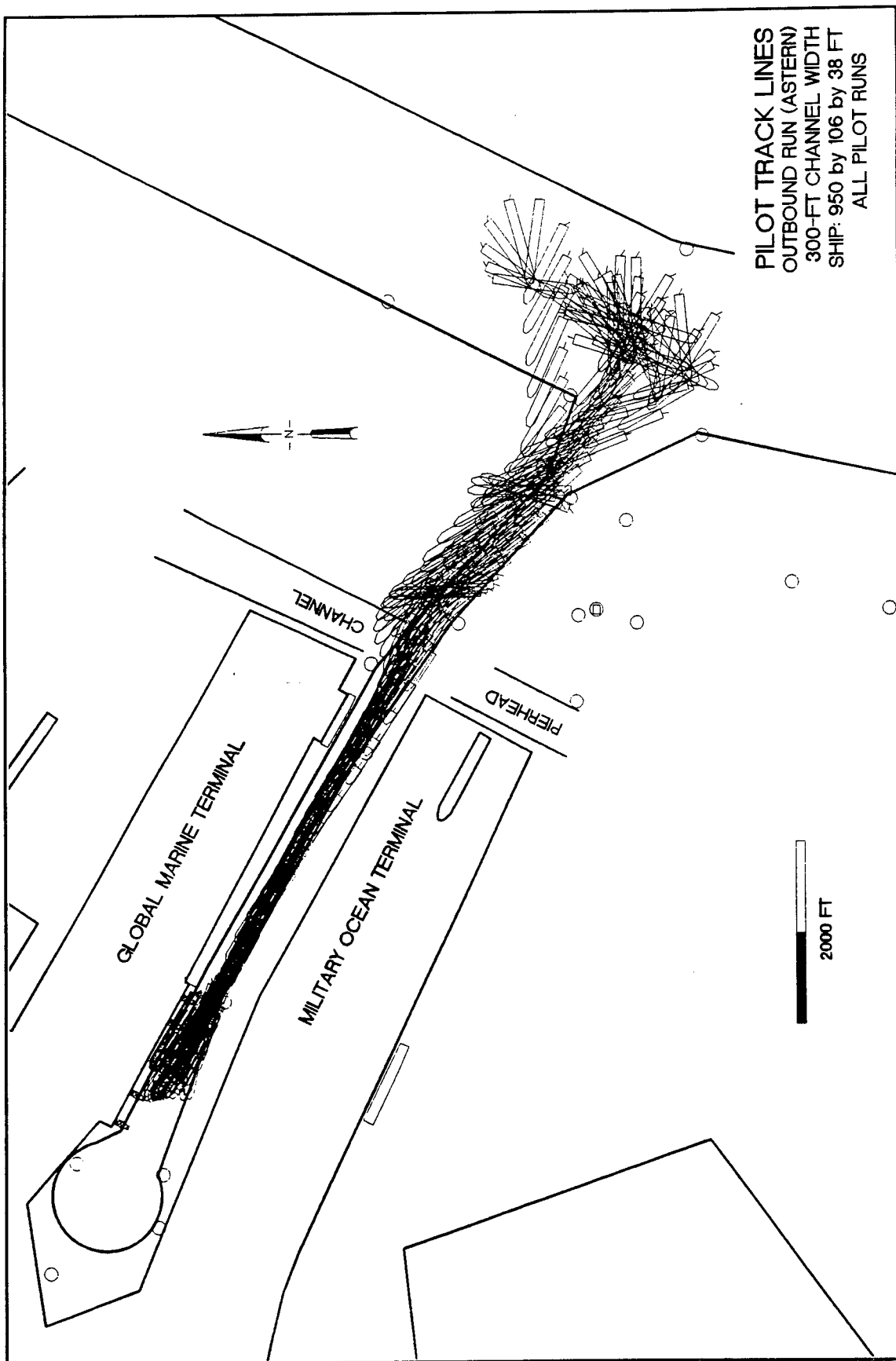
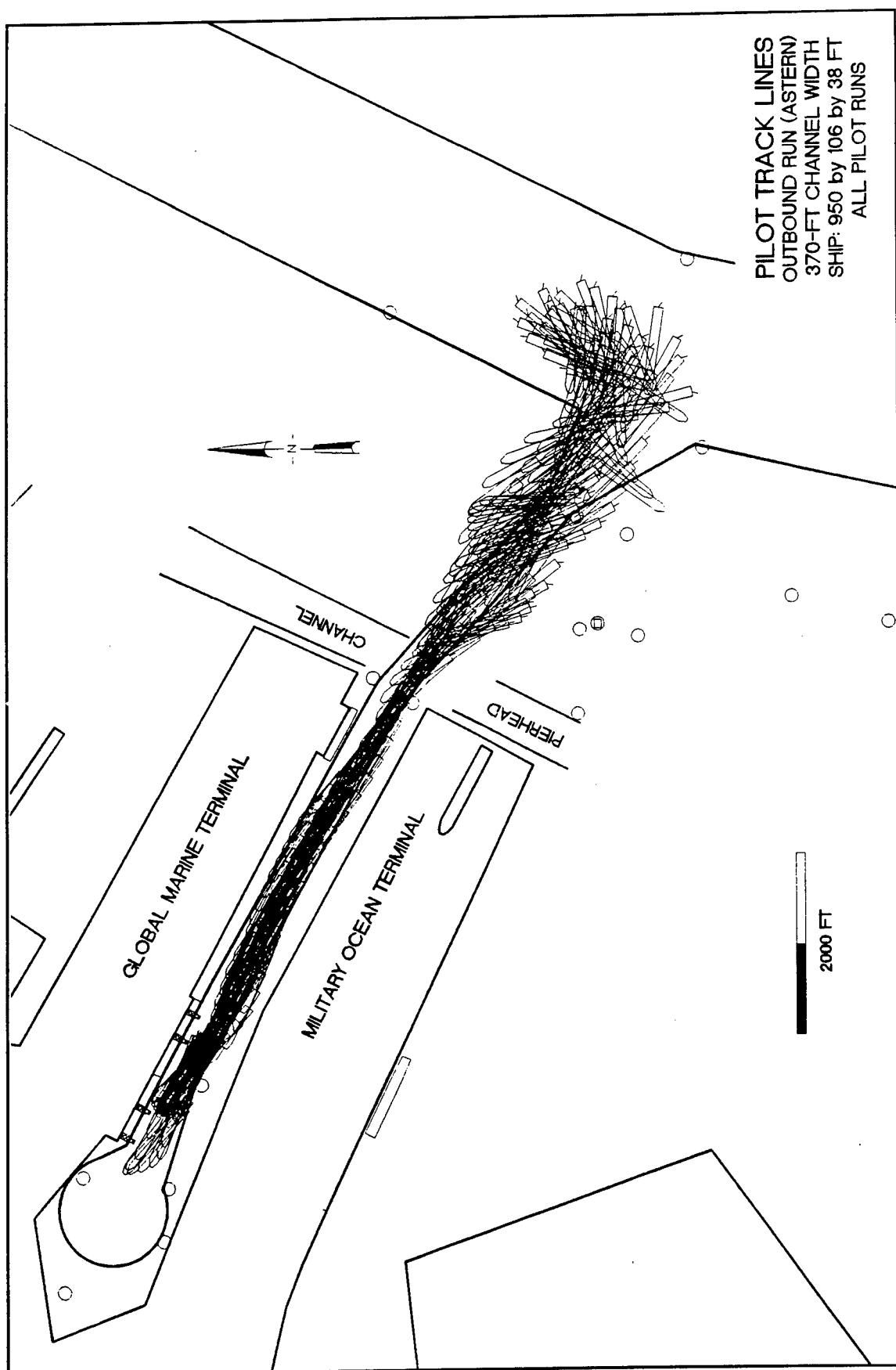


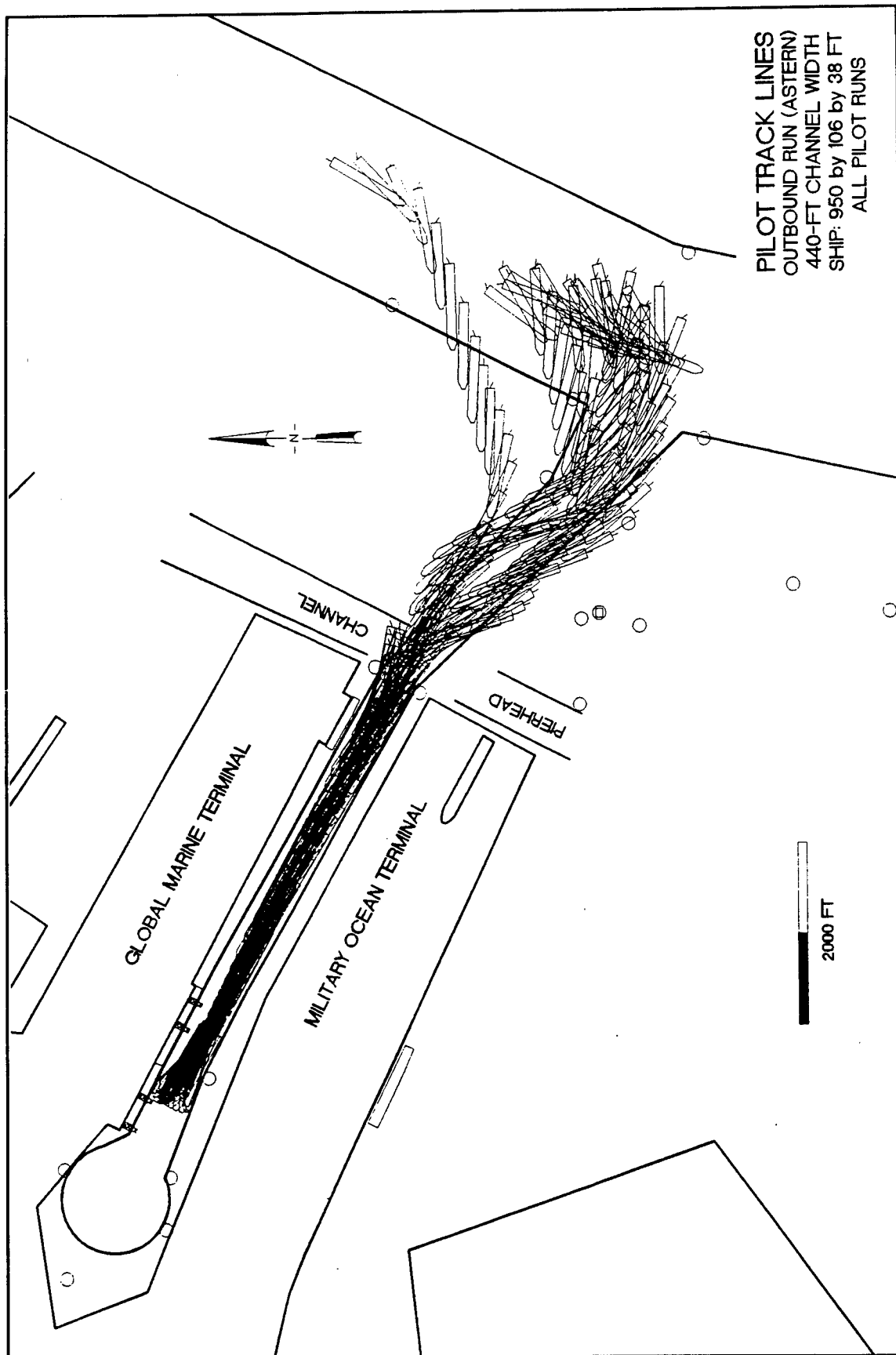
Plate 24

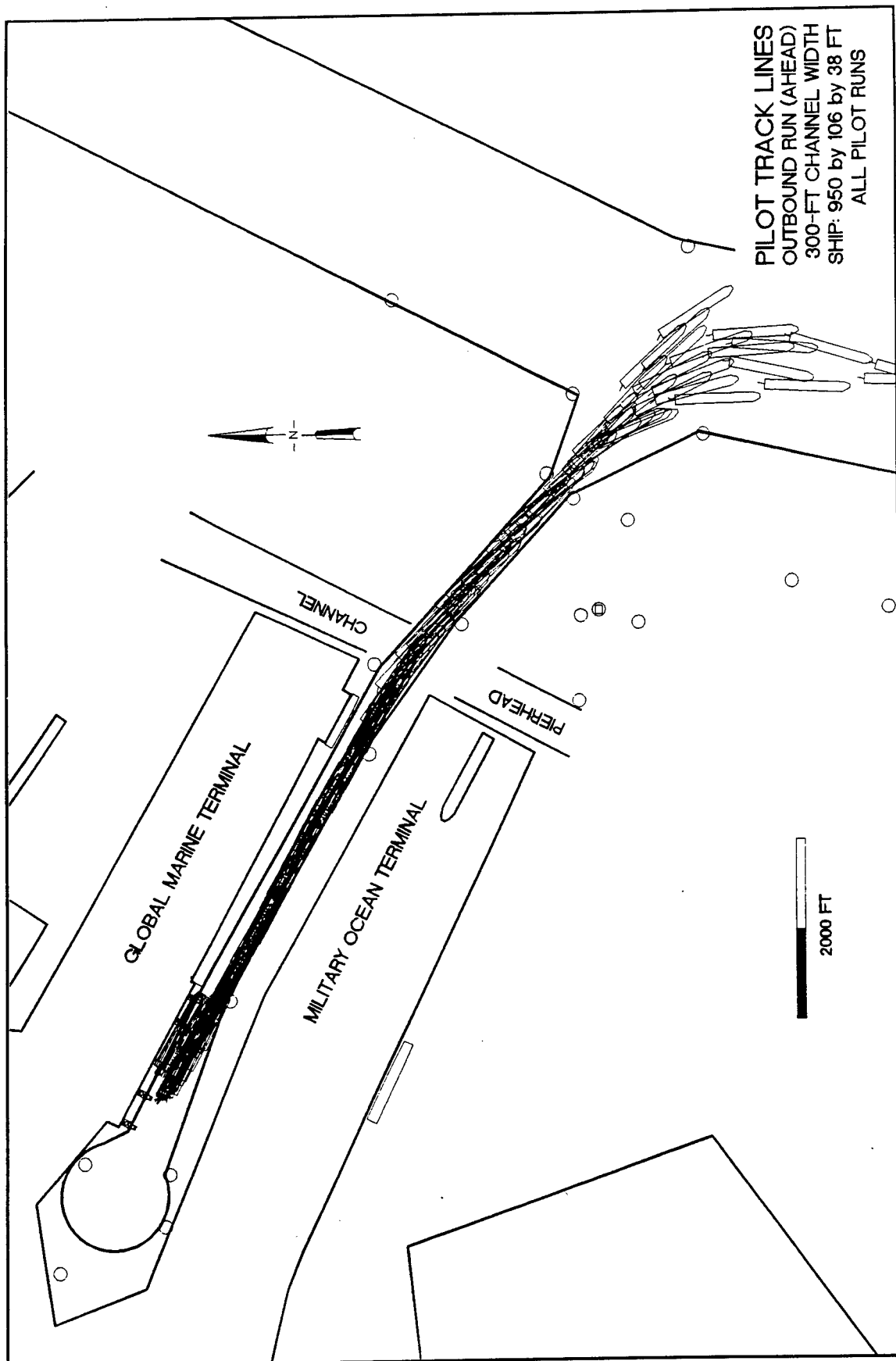


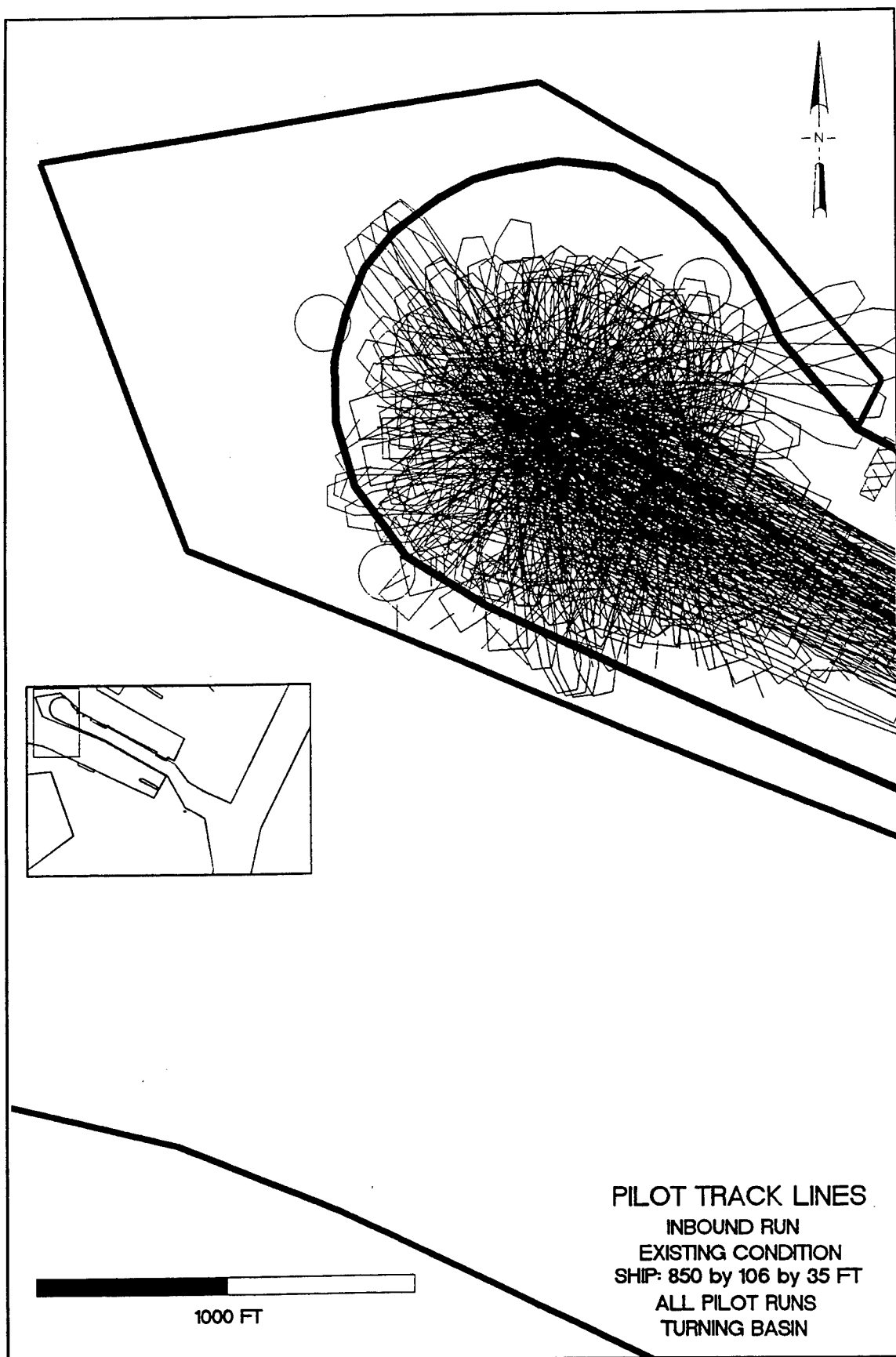


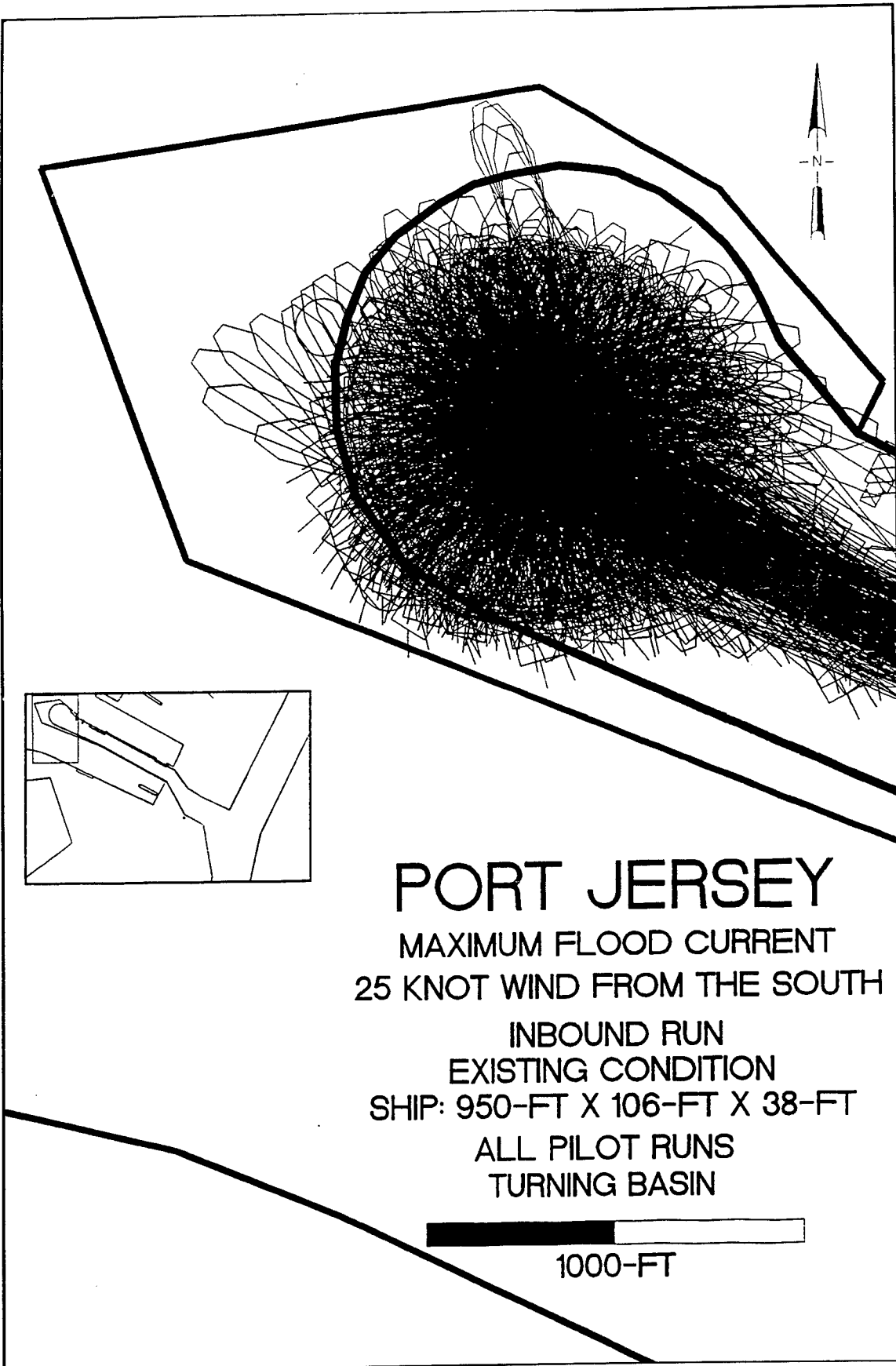


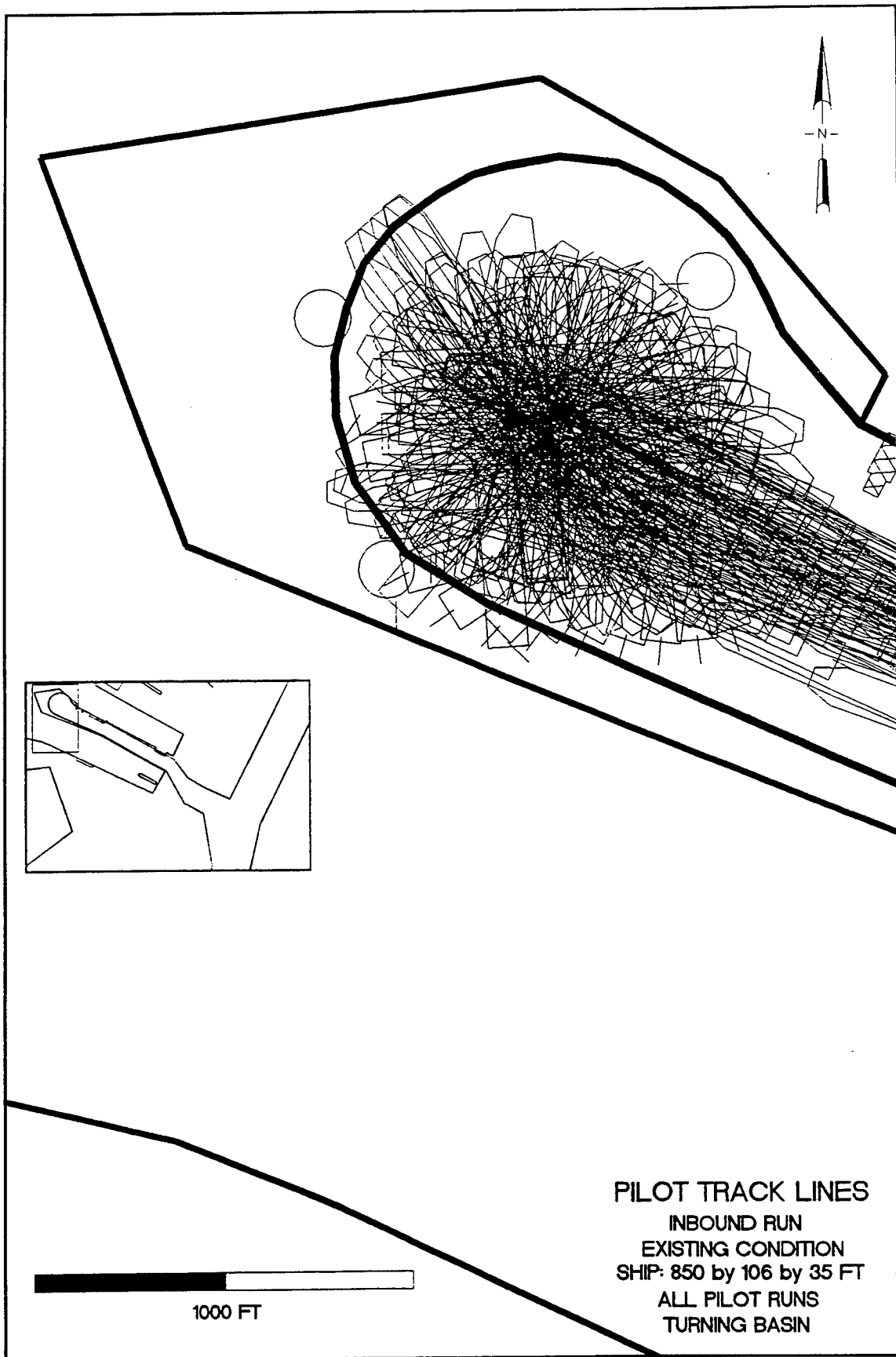


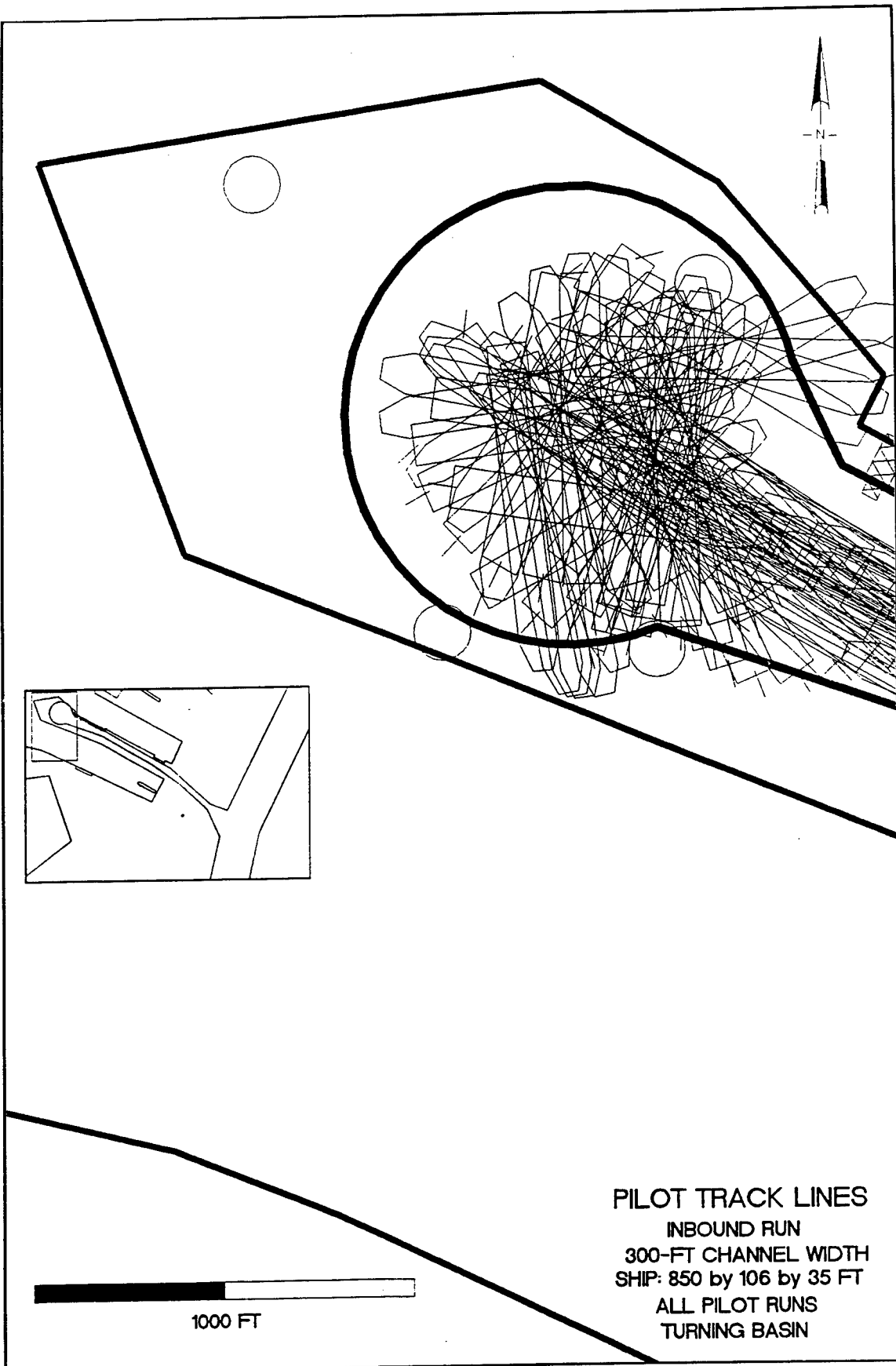


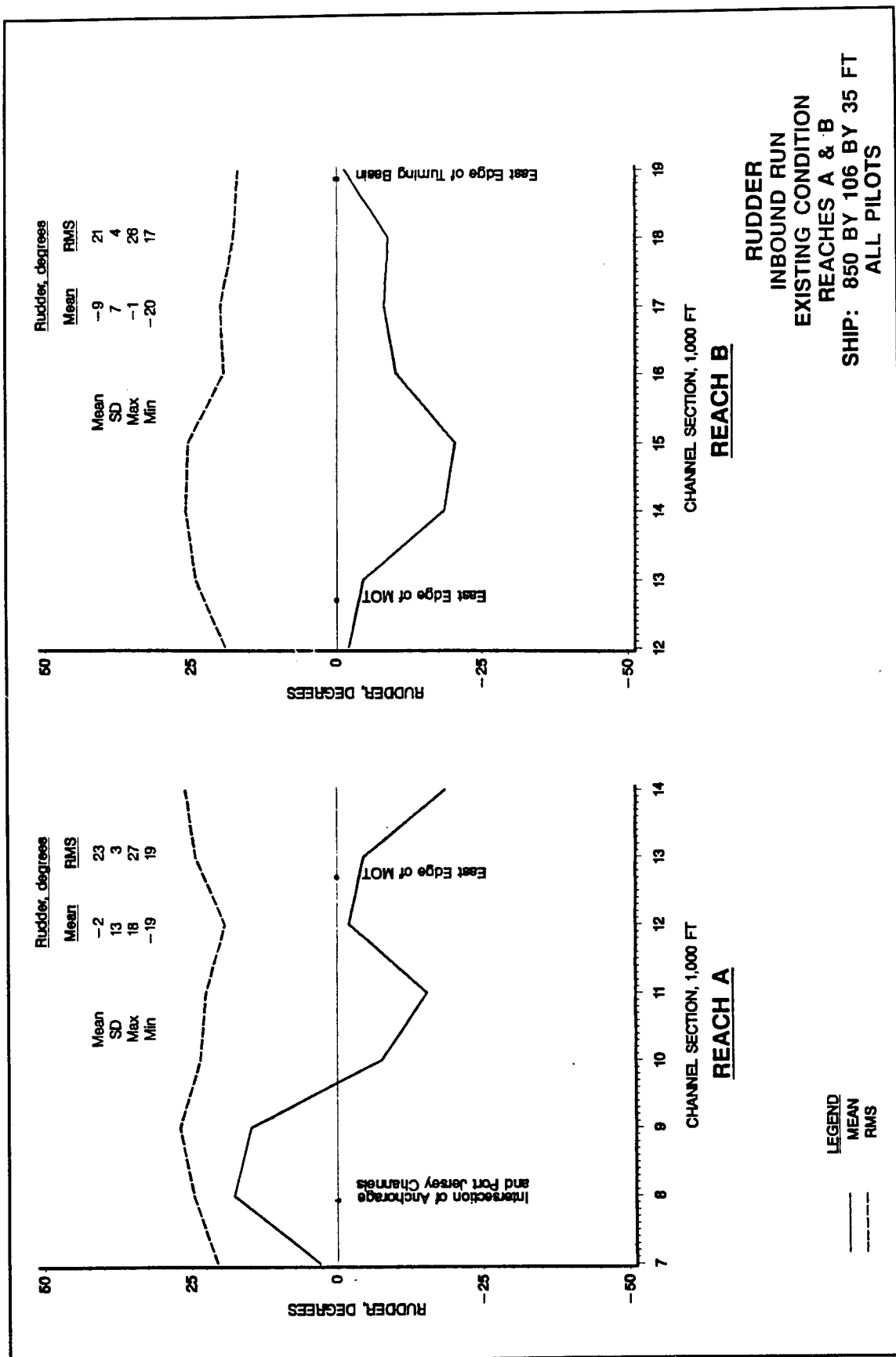


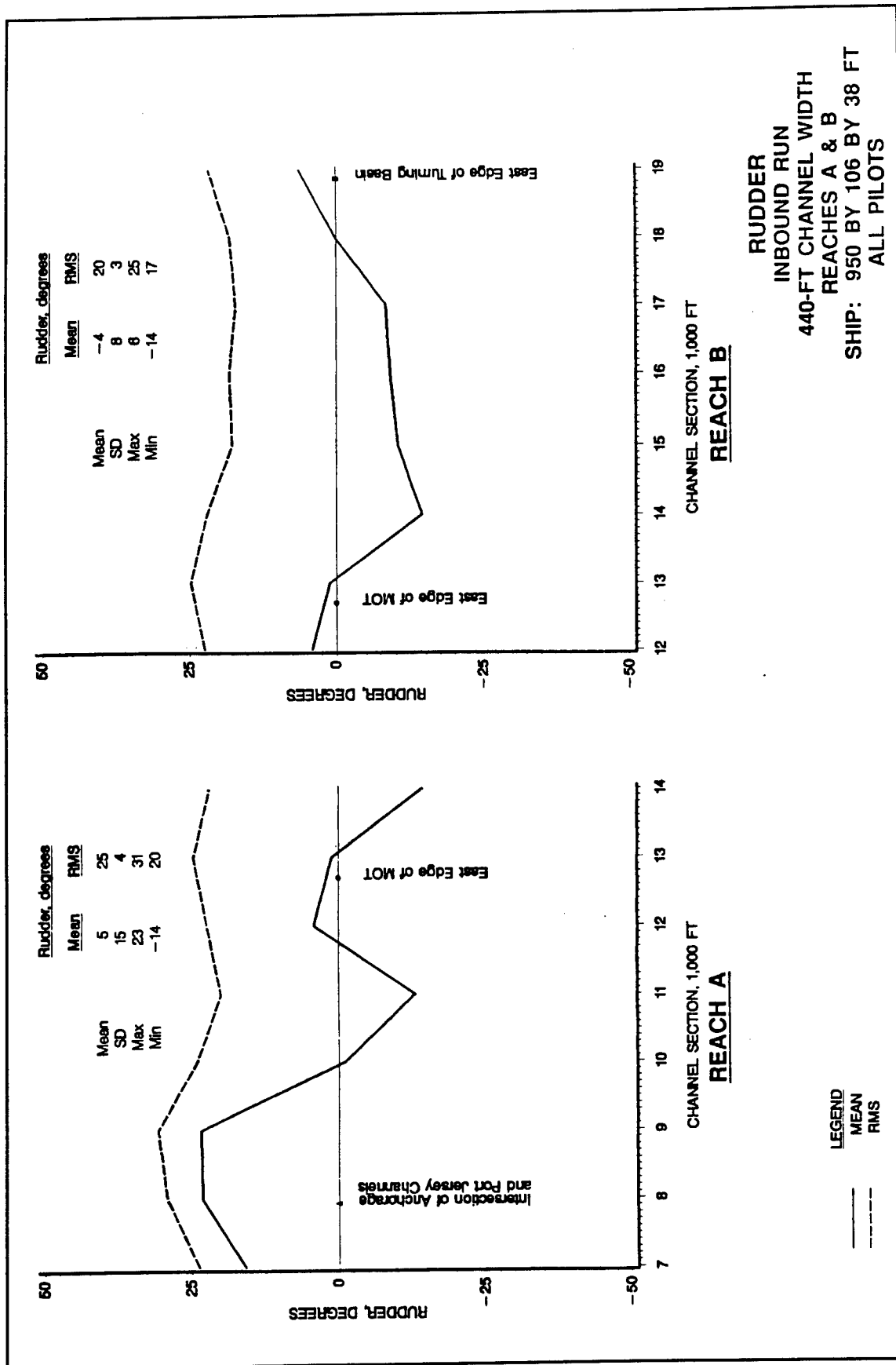






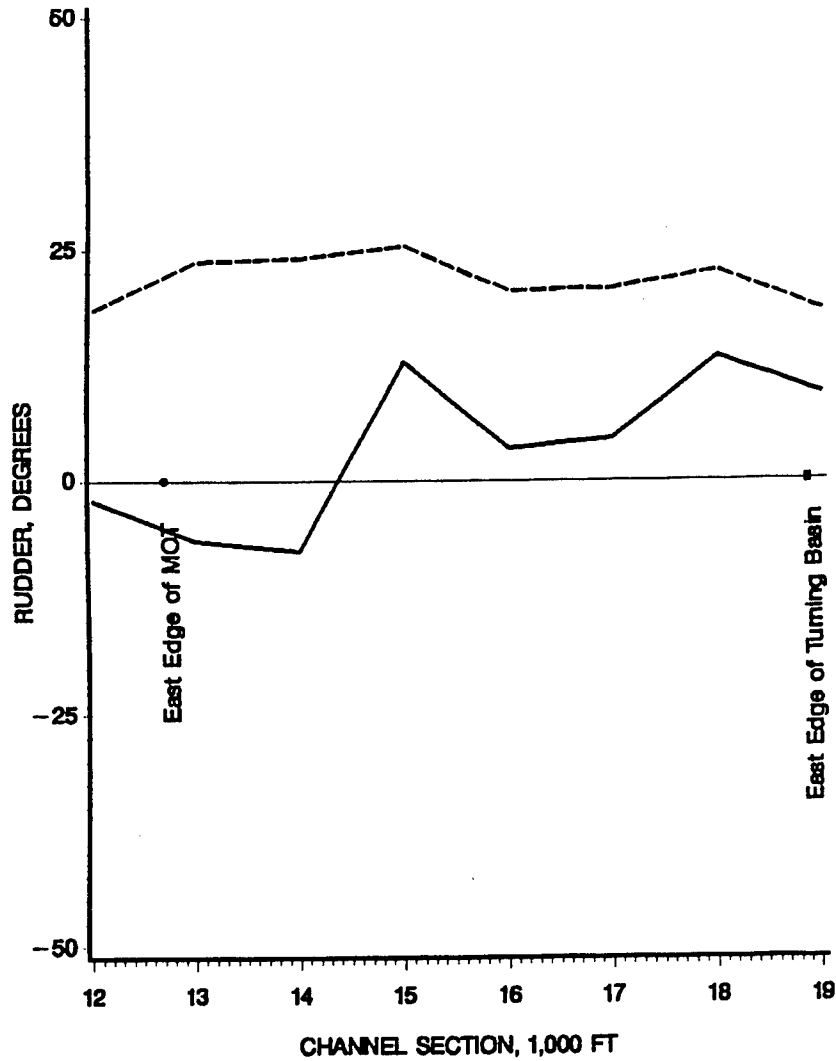






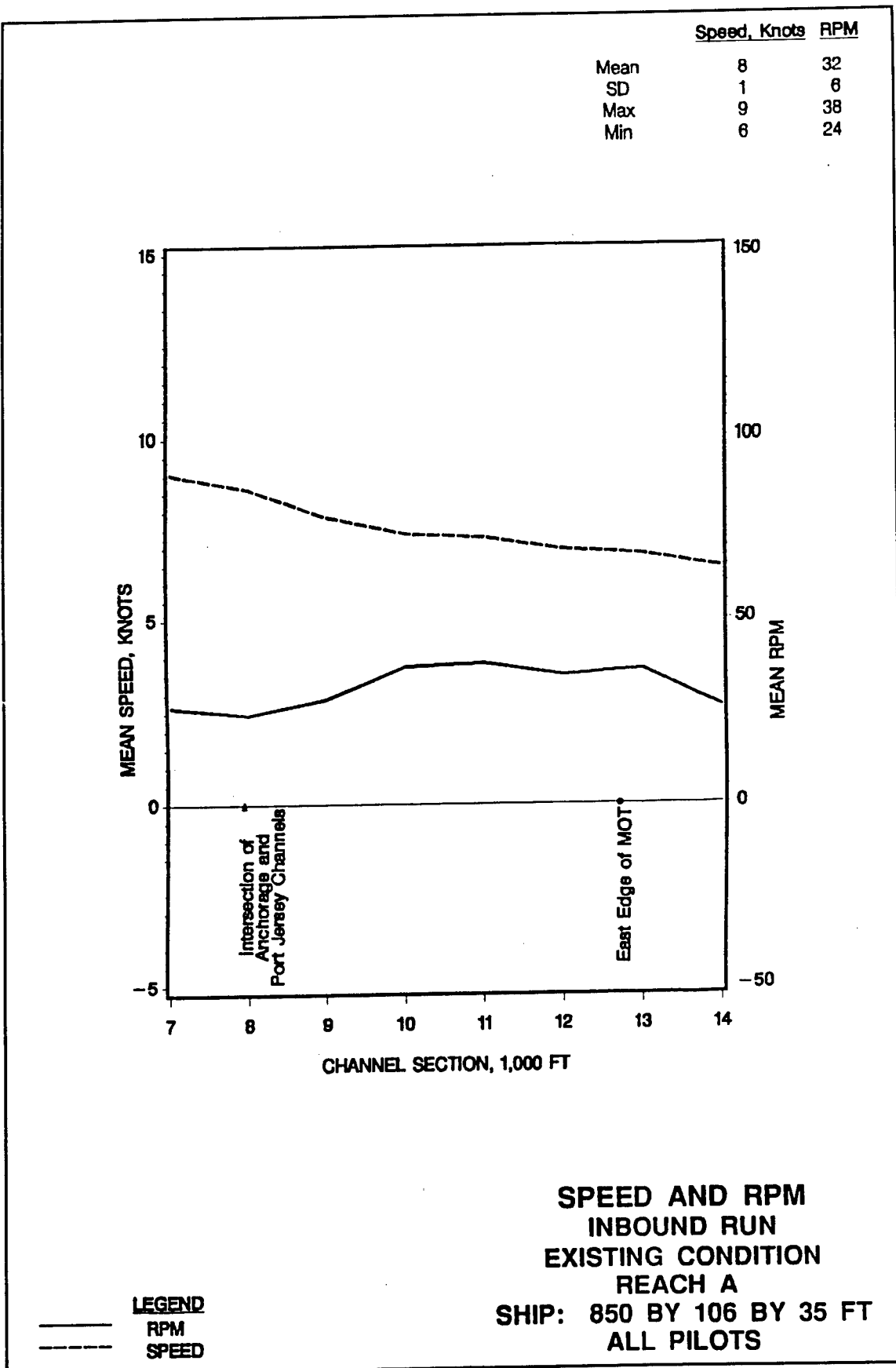
Rudder, degrees

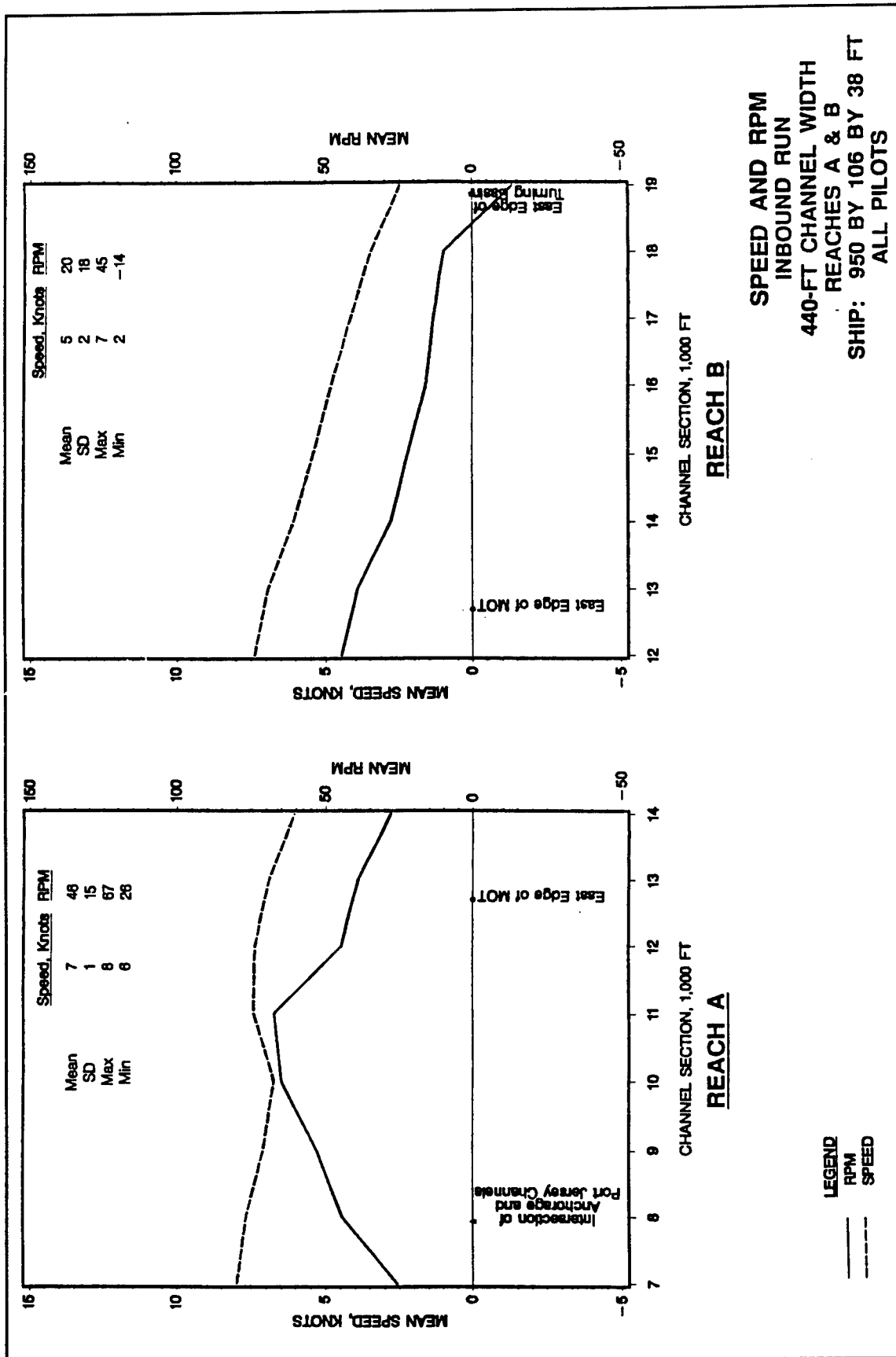
| | <u>Mean</u> | <u>RMS</u> |
|------|-------------|------------|
| Mean | 3 | 22 |
| SD | 8 | 3 |
| Max | 13 | 25 |
| Min | -7 | 18 |

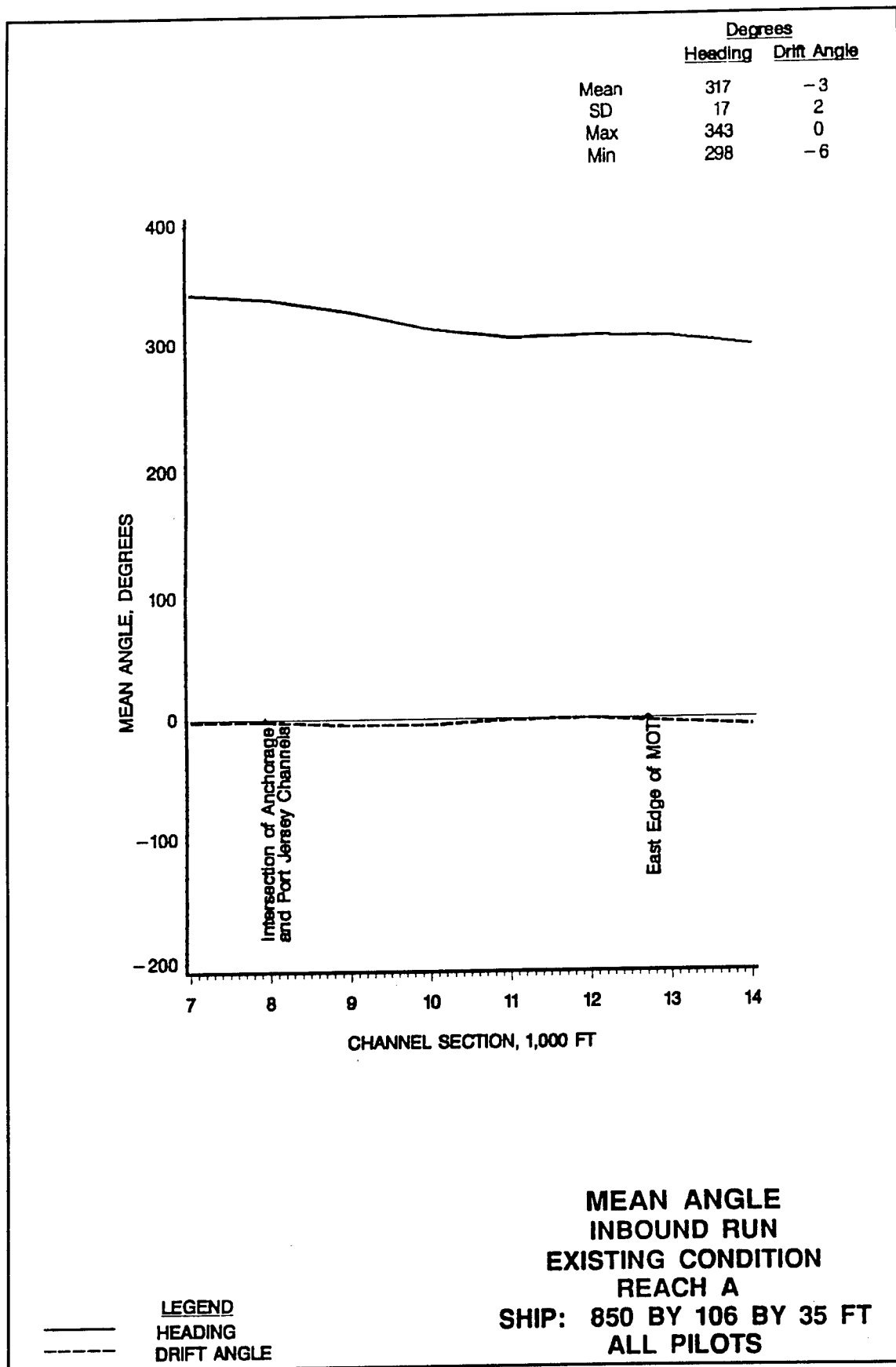


**RUDDER
INBOUND RUN
300-FT CHANNEL WIDTH
REACH B
SHIP: 950 BY 106 BY 38 FT
ALL PILOTS**

LEGEND
—— MEAN
---- RMS

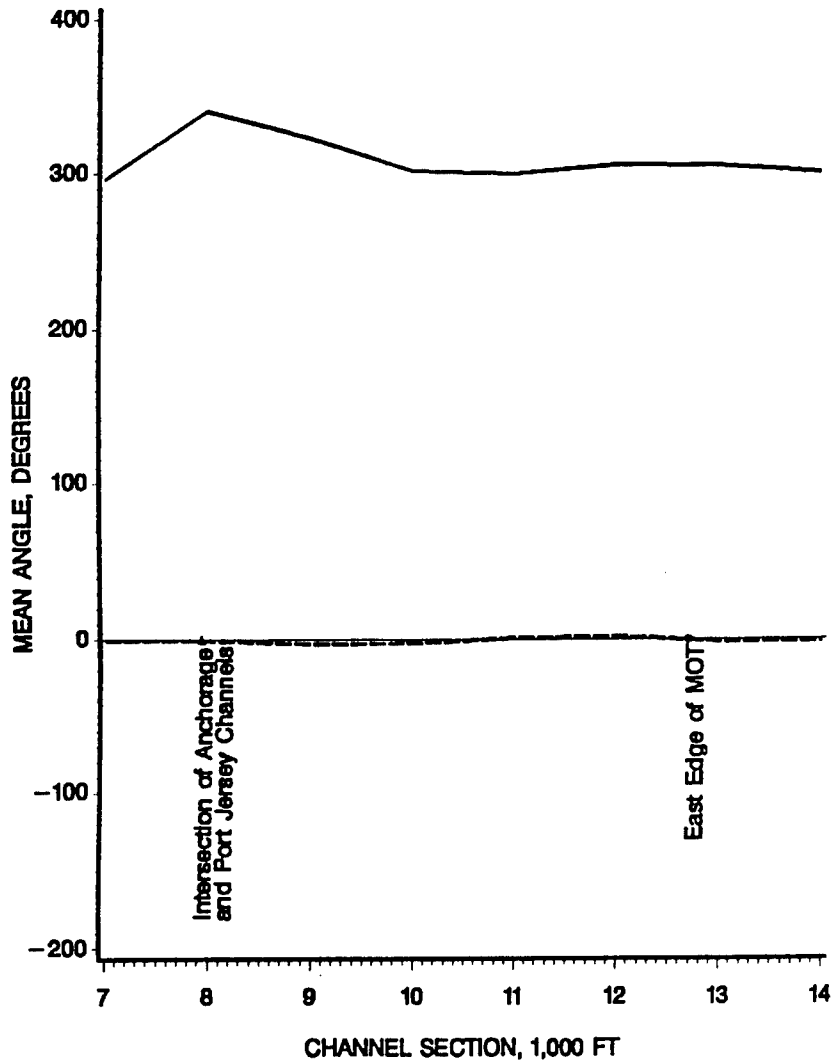






| | Degrees | |
|------|---------|-------------|
| | Heading | Drift Angle |
| Mean | 309 | -1 |
| SD | 15 | 2 |
| Max | 341 | 2 |
| Min | 298 | -3 |

| | | |
|------|-----|----|
| Mean | 309 | -1 |
| SD | 15 | 2 |
| Max | 341 | 2 |
| Min | 298 | -3 |

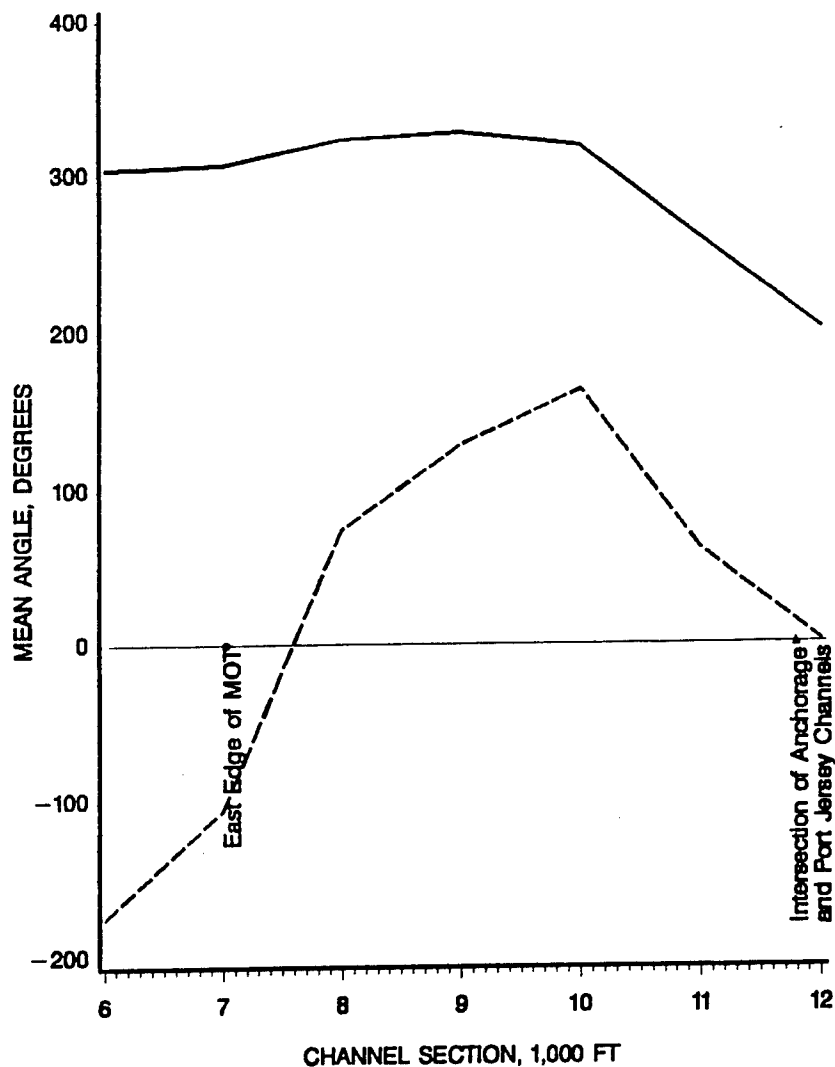


**MEAN ANGLE
INBOUND RUN
440-FT CHANNEL WIDTH
REACH A
SHIP: 950 BY 106 BY 38 FT
ALL PILOTS**

LEGEND
—— HEADING
---- DRIFT ANGLE

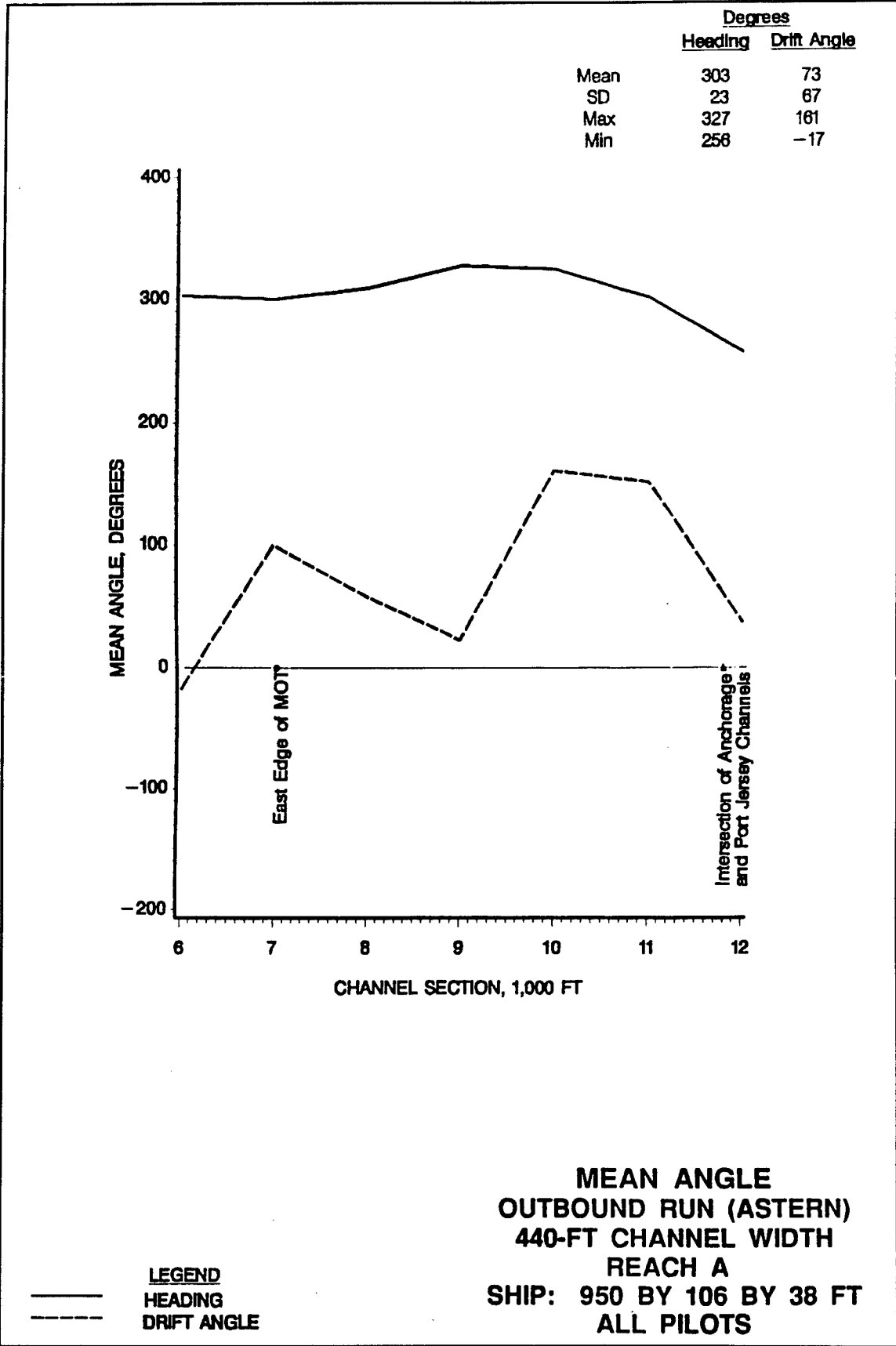
Degrees
Heading Drift Angle

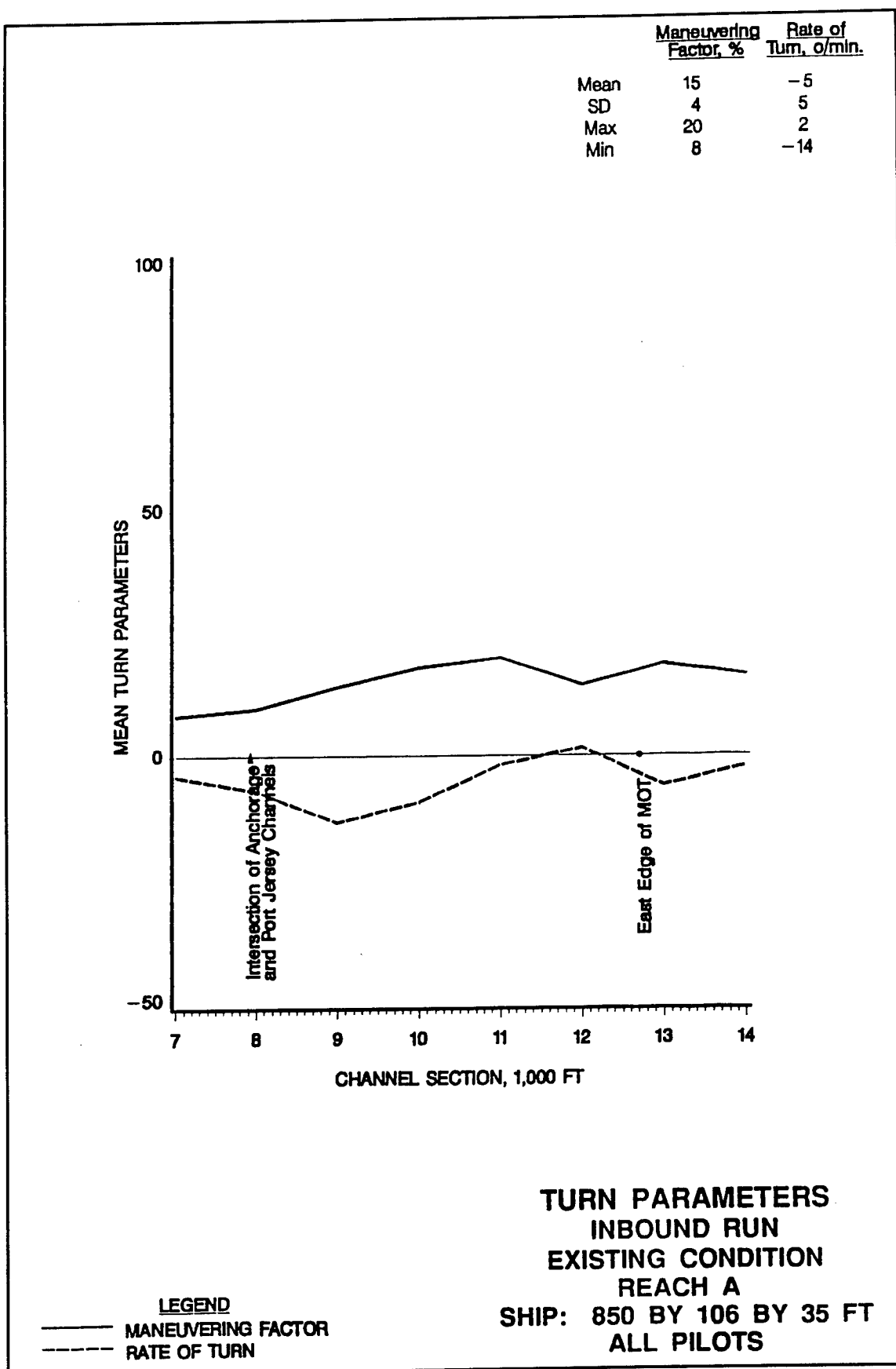
| | | |
|------|-----|------|
| Mean | 291 | 21 |
| SD | 45 | 123 |
| Max | 328 | 164 |
| Min | 201 | -176 |



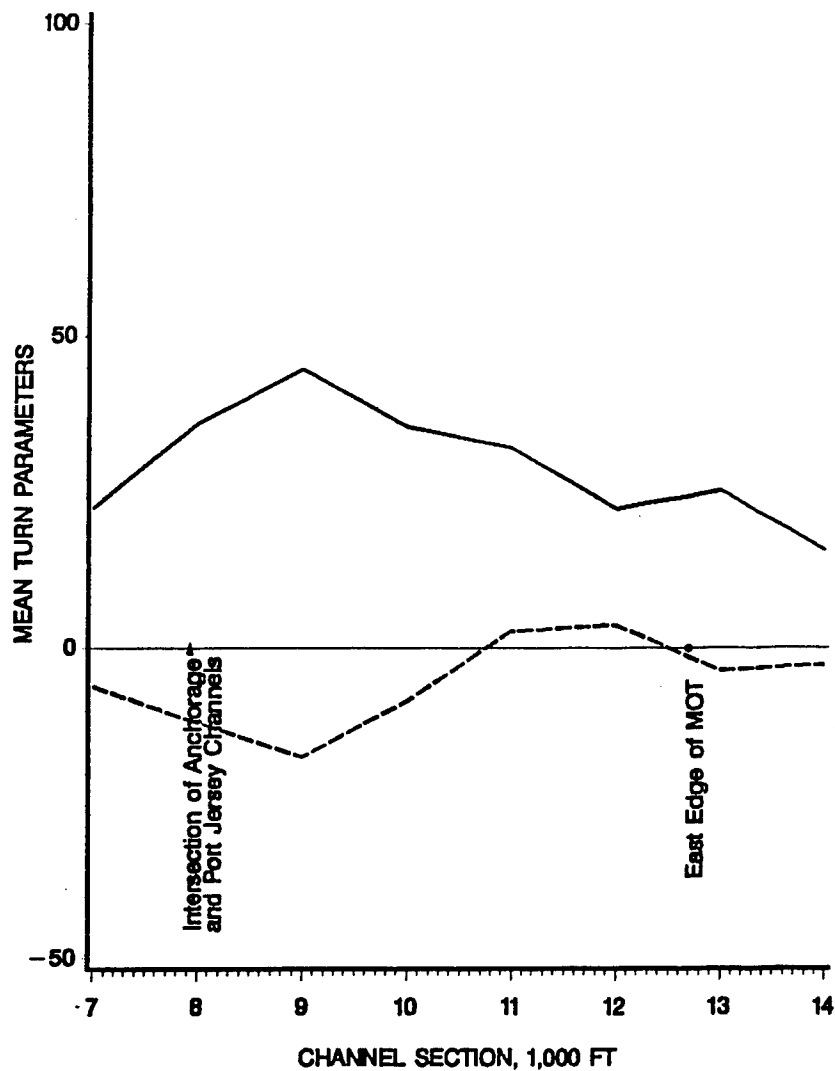
**MEAN ANGLE
 OUTBOUND RUN (ASTERN)
 EXISTING CONDITION
 REACH A
 SHIP: 850 BY 106 BY 35 FT
 ALL PILOTS**

LEGEND
 ——— HEADING
 - - - - - DRIFT ANGLE





| | <u>Maneuvering</u> <u>Factor, %</u> | <u>Rate of</u> <u>Turn, o/min.</u> |
|------|--|---------------------------------------|
| Mean | 29 | -5 |
| SD | 9 | 7 |
| Max | 45 | 4 |
| Min | 16 | -17 |



**TURN PARAMETERS
INBOUND RUN
440-FT CHANNEL WIDTH
REACH A
SHIP: 950 BY 106 BY 38 FT
ALL PILOTS**

LEGEND
—— MANEUVERING FACTOR
----- RATE OF TURN

| | | | |
|------|---|---|---|
| Mean | 0 | 2 | 1 |
| SD | 1 | 3 | 1 |
| Max | 3 | 7 | 3 |
| Min | 0 | 0 | 0 |



MEAN TUGS

Intersection of Anchorage and Port Jersey Channels

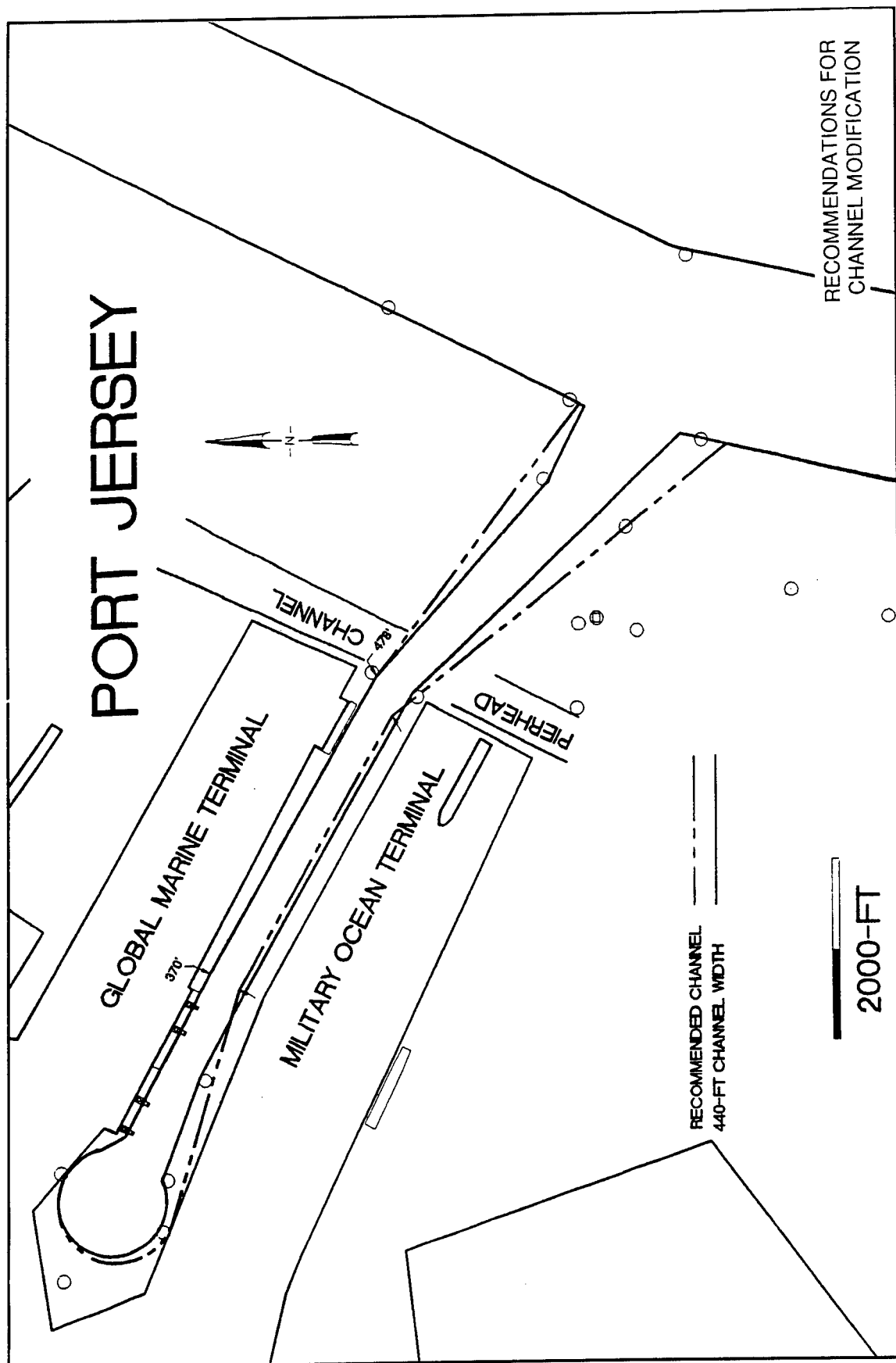
East Edge of MOT

CHANNEL SECTION, 1,000 FT

| Channel Section (1,000 FT) | Solid Line (Mean Tugs) | Dash-Dot Line (Mean Tugs) | Dashed Line (Mean Tugs) |
|----------------------------|------------------------|---------------------------|-------------------------|
| 7 | 0 | -10 | -10 |
| 8 | -5 | -10 | -10 |
| 9 | -10 | -20 | -20 |
| 10 | -5 | -5 | -50 |
| 11 | 2 | 0 | -65 |
| 12 | 3 | 2 | -45 |
| 13 | 4 | 3 | -30 |
| 14 | 10 | 2 | -35 |

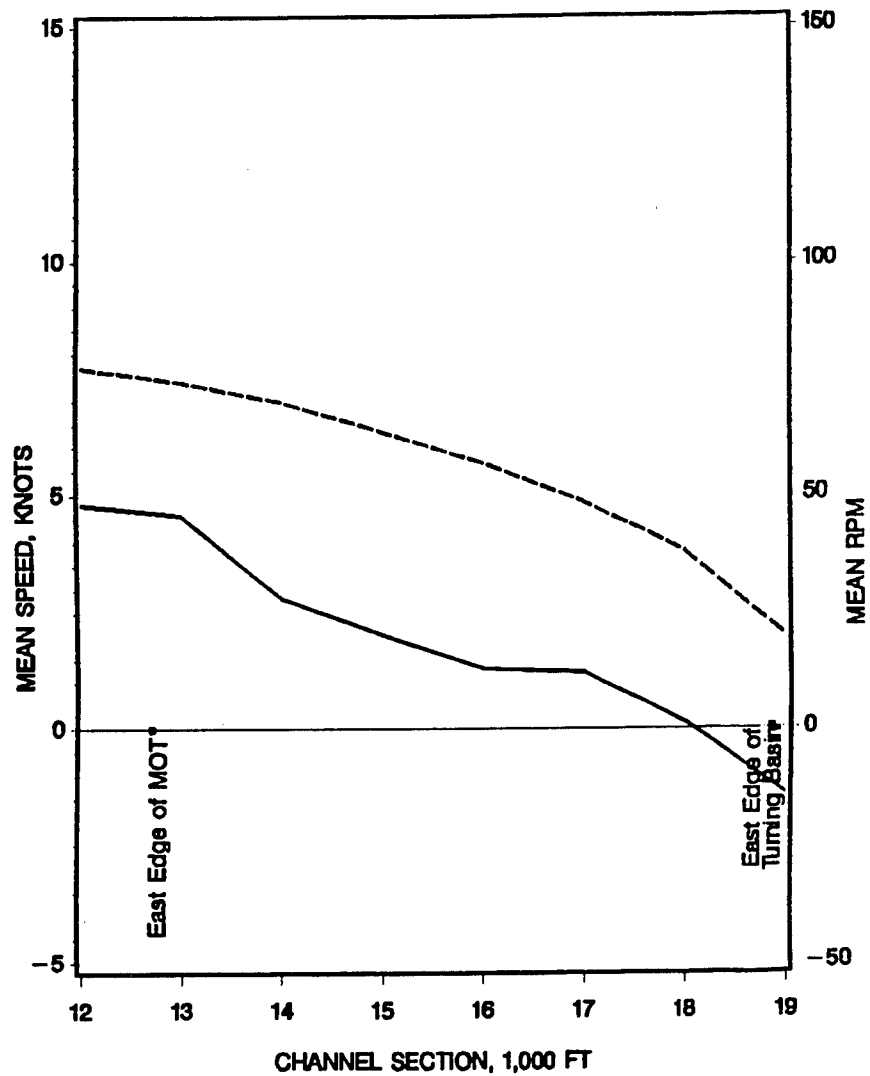
LEGEND

| | |
|---------|---------------------|
| ----- | PERPENDICULAR FORCE |
| ===== | PARALLEL FORCE |
| -----.. | MOMENT |



Speed, Knots RPM

| | | |
|------|---|-----|
| Mean | 6 | 19 |
| SD | 2 | 21 |
| Max | 8 | 48 |
| Min | 2 | -14 |



**SPEED AND RPM
INBOUND RUN
370-FT CHANNEL WIDTH
REACH B
SHIP: 950 BY 106 BY 38 FT
ALL PILOTS**

LEGEND
—— RPM
---- SPEED

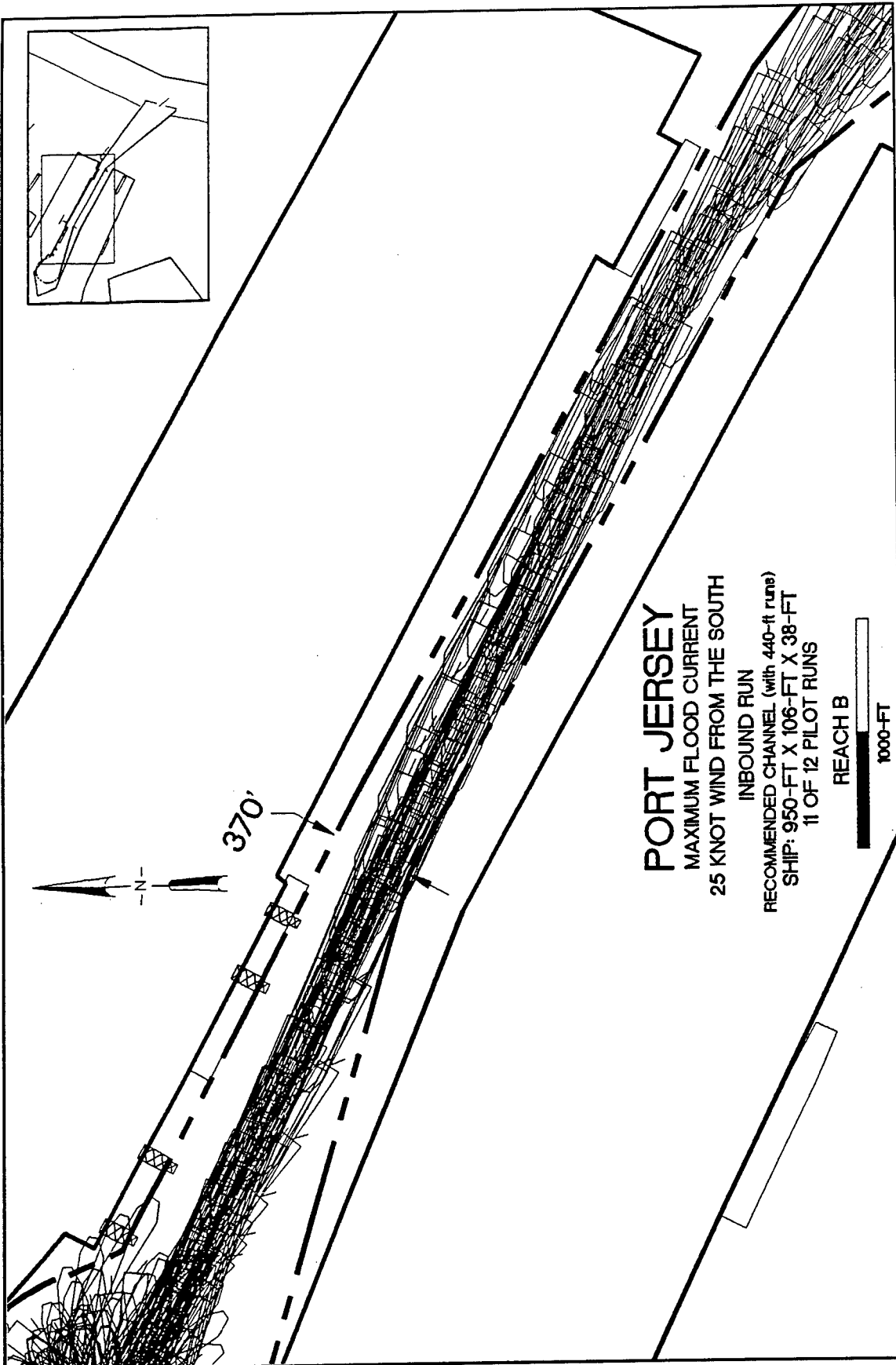


Plate 50

REPORT DOCUMENTATION PAGEForm Approved
OMB No. 0704-0188

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| | | | | |
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| 4.TITLE AND SUBTITLE Ship Navigation Simulation Study, Port Jersey Channel, Bayonne, New Jersey; Volume I: Main Text | | | 5.FUNDING NUMBERS | |
| 6.AUTHOR(S) Michelle M. Thevenot, Carl J. Huval, Larry L. Daggett | | | | |
| 7.PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Engineer Waterways Experiment Station 3909 Halls Ferry Road Vicksburg, MS 39180-6199 | | | 8.PERFORMING ORGANIZATION REPORT NUMBER Technical Report HL-96-19 | |
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| 11.SUPPLEMENTARY NOTES Appendixes A-C were published under separate cover. Copies of this report and Appendixes are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161. | | | | |
| 12a.DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited. | | | 12b.DISTRIBUTION CODE | |
| 13.ABSTRACT (Maximum 200 words) <p>The Port Jersey Channel, Bayonne, NJ, is part of the New York Harbor complex, the leading port on the east coast of the United States. It is one of several channels branching off to the left from the main Anchorage Channel south of the Statue of Liberty. The Port Authority of New York and New Jersey is developing the channel for container ship terminals. The existing channel is 35 ft deep below MLW and approximately 750 ft wide with a 1,200-ft turning basin at the end. The proposed improvements include deepening to 41 ft with a channel width of 300 ft. The purpose of the simulation study was to determine the effect of deepening the channel and to aid in design of the dimensions and alignment of the recommended channel.</p> <p>The ship simulation study was conducted by local tug pilots on the simulator and used tidal current data from a mathematical model using the TABS-2 modeling system. Two container ship models loaded to 35- and 38-ft draft were used in the existing and proposed channel test scenarios, respectively. Channel widths tested included the existing channel and widths of 250, 300, 370, and 440 ft. Test results used to evaluate the alternative channel plans included pilot ratings, composite ship track plot results, and statistical analysis of key ship navigation parameters, such as rudder angles, ship speed, ship heading, drift angles, etc.</p> <p style="text-align: right;">(Continued)</p> | | | | |
| 14.SUBJECT TERMS Navigation channels New Jersey Harbor New York Harbor | | | 15.NUMBER OF PAGES 92 | |
| Port Jersey Channel Ship channel Ship simulation | | | 16.PRICE CODE | |
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13. (Concluded).

The study results are contained in a set of channel design recommendations as follows:

- a.* Based on the simulation results, the nominal recommended channel width should be 370 ft.
- b.* The channel entrance from the Anchorage Channel should be increased in width starting at 1,700 ft wide and flaring down to 370 ft.
- c.* Additional channel width should be provided for ship maneuvering in and out of the turning basin at the far end of the channel.
- d.* Enlarging the size of the turning basin to 1,300-ft diameter should be considered.
- e.* If the increased channel size is cost prohibitive, consideration of limiting operations during high tidal crosscurrents and winds should be contemplated.
- f.* Pilot training on a simulator may also help in improving ship control performance and overcome to some degree the inability to widen the channels because of high costs.